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CULTURAL STUDIES WITH BARLEY III

The Effects of Cultural Practices on Malting Quality[1]

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The earlier papers in this series (7, 8) dealt with the effects of cultural practices on the yield of three varieties of barley. Increase in yield is an important aspect of barley culture, but the effects of cultural practices on malting quality are no less important. This is particularly true in Manitoba where a large number of farmers grow barley as a cash crop. For this reason the investigations on malting quality reported here were made on material obtained in cultural studies with the barley crop. The results are presented in this paper.

The design of the experiments was given in detail in Part I (7) and need not be repeated. In evaluating the malting qualities of the samples the criteria outlined by Meredith, Rowland and Anderson (6) were followed. These may be summarized by stating that the quantity of malt extract is the most important single factor in evaluating malts. This should be as high as possible. It is directly related to amount of heavy grade barley and inversely related to nitrogen content. The enzymatic properties measured commonly by diastatic power play an important part in producing malt extract, and the supply of enzymes should be adequate to produce sufficient growth to convert the starch and protein in the kernel into soluble form. The ratio of nitrogen to sugar in the extract is also important; and although extract quality is not fully understood, the percentage nitrogen in the wort is a useful guide to extract quality. While the optimum amount of wort nitrogen is not fully defined at present, it is generally assumed that values for this quality much higher or much lower than that for a comparable sample of the standard variety, O.A.C. 21, are undesirable. High barley nitrogen content, as well as reducing malt extract, increases wort nitrogen content and further lowers malt quality.

MATERIALS AND METHODS

The replicate samples of each treatment grown in 1937 at Winnipeg and Carman were bulked to provide samples for malting tests, producing 81 samples from each station. There were no samples from Swan River for that year owing to destruction by hail, and the Newdale samples were too

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small to provide enough grain for malting tests. The samples from the 1938 crop were treated similarly; but those representing the medium rate of fertilizer were not malted, since the previous year's tests indicated that the two rates of fertilizer were indistinguishable in their effects. Samples were obtained from all four stations, providing 216 samples in all. No malting tests were carried out on the 1939 crop samples as it appeared that sufficient evidence on the effects of cultural practices on malting quality had already been obtained.

The samples were malted and analysed by the standard procedures reported by Anderson and Rowland (2). Nitrogen and 1,000 kernel weight determinations were made in the Malting Laboratory, and wort nitrogen determinations were carried out by the method described by Meredith and Anderson (5).

RESULTS

The data for each year, for the important barley and malt determinations, are summarized in Table 1 as means for each factor over all other

TABLE 1.—TOTAL EFFECTS OF VARIETY, DATE OF SEEDING, RATE OF SEEDING, RATE OF FERTILIZER AND STATION, ON MALTING QUALITY

	Heavy kernels		1,000 K. wt.		Nitrogen		Extract		D.P.		Wort N.	
	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938	1937	1938
	%	%	g.	g.	%	%	%	%	°L.	°L.	%	%
Variety												
O.A.C. 21	53.5	44.6	28.2	26.4	2.22	2.32	72.1	71.5	140	152	1.22	1.31
Mensury	55.5	45.7	29.0	26.7	2.24	2.32	72.5	71.7	149	160	1.23	1.32
Gartons	66.1	67.0	29.4	29.9	2.61	2.73	72.2	72.3	150	166	1.26	1.33
Necessary difference	—	21.0	—	—	0.13	0.23	—	—	—	—	—	—
Date of seeding												
1	73.4	71.9	31.6	30.8	2.39	2.39	73.2	73.9	135	151	1.20	1.22
2	75.9	54.0	31.5	28.4	2.34	2.45	73.7	72.3	139	159	1.12	1.30
3	25.9	31.4	23.5	23.9	2.34	2.52	69.9	69.3	164	168	1.41	1.46
Necessary difference	24.4	19.8	5.4	4.4	—	0.09	2.7	2.4	—	—	—	0.22
Rate of seeding												
1—1 bu.	59.2	52.3	28.9	27.9	2.35	2.44	72.3	71.7	147	158	1.26	1.32
2—1¾ "	58.0	53.2	28.7	27.8	2.35	2.44	72.3	71.9	146	158	1.23	1.32
3—2½ "	58.0	51.8	28.9	27.3	2.36	2.49	72.3	71.8	146	162	1.24	1.33
Necessary difference	—	—	—	—	—	—	—	—	—	—	—	—
Rate of fertilizer												
Check—no fertilizer	57.4	49.8	28.5	27.2	2.35	2.45	72.2	71.7	148	158	1.24	1.32
40 lbs. 11-48-0	57.4	—	28.9	—	2.35	—	72.3	—	145	—	1.24	—
96 lbs. 16-20-0	60.4	55.0	29.2	28.2	2.37	2.47	72.3	72.0	146	161	1.24	1.32
Necessary difference	—	—	—	—	—	—	—	—	—	—	—	
Winnipeg	49.1	49.9	27.8	27.8	2.41	2.44	71.2	71.6	149	161	1.26	1.32
Carman	67.7	49.8	29.9	26.2	2.30	2.64	73.4	70.2	144	182	1.22	1.51
Newdale	—	33.3	—	24.7	—	2.64	—	71.1	—	171	—	1.30
Swan River	—	76.7	—	32.0	—	2.11	—	74.3	—	123	—	1.17
Necessary difference	13.1	22.9	—	5.1	—	0.26	—	2.8	—	29	—	0.25

factors. The data were subjected to separate analyses of variance (4), and from the resulting statistics the differences between levels of each factor that can be considered significant to the 5% level were calculated. These necessary differences are reported in the table only for the determinations and factors in which significant differences were observed. Where differences are small it is readily apparent that they are not significant, either statistically or practically; but where differences are large and not significant statistically they show that the differences in the mean values were not consistent, and varied at different levels of some other factor. There were no significant differences between rates of seeding or between rates of fertilizer, but there were differences between varieties and considerable differences between dates of seeding and between stations.

TABLE 2.—ANALYSES OF VARIANCE

Variance due to	D.F.	1937 Crop—Mean squares			D.F.	1938 Crop—Mean squares		
		Nitrogen	Heavy	Extract		Nitrogen	Heavy	Extract
		%	%	%		%	%	%
Treatments	26	0.2008**	233.9	0.5567	17	0.4765**	1534.5**	2.7697
Dates	2	0.0430	42877.0**	236.7939*	2	0.2969*	29612.6**	404.2512**
Stations	1	0.4408	13990.9*	191.8622	3	3.2767**	17412.9*	170.0019
T × D	52	0.0100*	185.5**	2.6138**	34	0.0086	292.8**	4.1314**
T × S	26	0.0057	46.1	0.3433	51	0.0473**	92.5**	3.1113**
D × S	2	0.0864**	374.3**	11.8716**	6	0.0275**	2344.6**	36.2820**
T × D × S	52	0.0062	46.1	0.6397	102	0.0090	48.9	1.3457
Treatments								
Varieties	2	2.5649**	2478.4	2.4857	2	3.9360**	11489.8	13.3338
Rates	2	0.0008	27.9	0.0479	2	0.0503	35.4	0.7010
Fertilizer	2	0.0056	108.3	0.3072	1	0.0214	1427.1	4.8893
V × R	4	0.0039	107.5*	0.4768	4	0.0076	153.6*	1.1978
V × F	4	0.0036	27.9	0.4196	2	0.0038	402.8**	3.6728*
R × F	4	0.0015	12.8	0.3879	2	0.0007	49.9	0.0202
V × R × F	8	0.0054	19.8	0.4585	4	0.0162	22.2	0.4874
T × D								
V × D	4	0.0577	2061.3**	25.4789**	4	0.0356**	2048.3**	30.1806**
R × D	4	0.0242	29.7	2.7835	4	0.0025	178.4	0.2706
F × D	4	0.0032	78.6	1.2222	2	0.0056	73.6	5.7724
Error	40	0.0045	24.2	0.4527	24	0.0054	37.5	0.2965
T × S								
V × S	2	0.0350	98.1	0.1672	6	0.3100**	341.6	20.4921*
R × S	2	0.0061	82.4	0.1116	6	0.0164	70.8	0.0303
F × S	2	0.0044	207.6	0.7886	3	0.0026	260.8	4.5415
Error	20	0.0028	21.1	0.3409	36	0.0124	40.5	0.6088
T × D × S								
V × D × S	4	0.0159*	48.0	1.8152**	12	0.0098	103.7**	5.4460**
R × D × S	4	0.0065	139.8**	0.8163	12	0.0093	75.5*	0.8030
F × D × S	4	0.0092	84.5	0.8639	6	0.0092	65.8	3.0002**
Error	40	0.0050	32.8	0.4821	72	0.0088	33.9	0.6149

* Significantly greater than mean square due to greatest error affecting differentiation.
Single signs denote that the 5% level of significance is attained.
Double signs denote that the 1% level of significance is attained.

In order to explain the reason for the statistical non-significance of comparatively large differences, it is necessary to examine the results of the statistical analyses. These, for barley, nitrogen content, percentage heavy kernels and malt extract, are given in Table 2. These properties are the most important of the barley and malt qualities listed in Table 1.

Within varieties, kernel weight is obviously directly related to percentage heavy kernels. Diastatic power and wort nitrogen content, as has been amply demonstrated in other investigations (3, 5) are directly related, within varieties, to barley nitrogen content. The malting quality of barley may then be conveniently discussed in terms of percentage heavy kernels, nitrogen content and malt extract, with little loss of information owing to the relationships between these properties and other barley and malt properties.

The data in Table 2 show that, among the simple comparisons, the effects of dates of seeding and stations were of large magnitude and the majority of the mean squares are significant. While large differences between varieties are indicated, they are significant only in nitrogen content. The mean squares for rates are of small magnitude and they are insignificant. The mean squares for fertilizer are also not significant, but some are of relatively large magnitude.

The outstanding feature of the remaining data is that the mean squares due to interaction between varieties and dates are, with the exception of that for the nitrogen content of the 1937 crop samples, highly significant. In other words, varietal positions changed markedly from date to date. Other interactions worthy of mention are those reflecting: the differences between stations in variety-date reactions; the differences between dates at different stations; the differential response of varieties to rate of seeding with respect to percentage heavy kernels; the differential response of varieties to fertilizer in 1938; the differential response of varieties to change in environment; the differences between stations in rate-date reaction with respect to percentage heavy kernels; and the difference between stations in fertilizer date reactions with respect to malt extract in the 1938 crop samples.

Data illustrating the interactions between the various factors are given in Tables 3 to 9. Necessary differences, for significance to the 5% level, were calculated from the appropriate mean squares and these are included in the tables.

DISCUSSION

Effect of Date of Seeding

In general, as is shown in Table 1, the effects of late seeding were to reduce the quality of the barley by reductions in percentage of heavy grade barley, in kernel weight and in malt extract yield. In 1937 the decreases in these qualities were not evident until the third date of seeding, but in 1938 the decreases were progressive from first to third seeding date. There were no significant differences between dates with respect to nitrogen content in 1937, but in 1938 delayed seeding caused progressive increases in nitrogen content. In 1937, although the range in wort nitrogen content among dates of seeding was considerable, the differences were not statistically significant, but in 1938 the effect of delay was to increase wort

nitrogen content. No significant differences with respect to diastatic power were demonstrated between dates of seeding in either year. In both years the barley from the third date would be considered unfit for malting, largely because of the high percentage of thin kernels.

The differential response of varieties to date of seeding that was noted in a previous section is illustrated in Tables 3 and 4. These give the data for the three important properties as means for each variety at each date of seeding at each station for each year. The mean values in the section of the tables show that O.A.C. 21 and Mensury[5] behaved similarly in response to delayed seeding. Gartons did not react in the same way as the

TABLE 3.—DATA ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT, ILLUSTRATING INTERACTIONS BETWEEN VARIETIES, DATES OF SEEDING AND STATIONS, 1937 CROP

Variety	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
	%	%	%	%	%	%	%	%	%	%	%	%
Winnipeg												
O.A.C. 21	2.23	2.29	2.24	2.25	59.6	67.4	5.2	44.1	72.9	73.0	67.1	71.0
Mensury	2.27	2.32	2.27	2.29	63.8	72.3	6.8	47.6	73.3	73.4	67.5	71.4
Gartons	2.70	2.58	2.78	2.68	60.4	67.2	39.0	55.6	71.1	72.3	70.2	71.2
Mean	2.40	2.39	2.43	2.41	61.3	69.0	17.0	49.1	72.4	72.9	68.3	71.2
Carman												
O.A.C. 21	2.29	2.20	2.10	2.20	84.5	82.9	21.5	62.9	74.4	74.8	70.6	73.2
Mensury	2.28	2.17	2.10	2.18	83.7	80.5	26.0	63.4	74.5	75.1	71.4	73.6
Gartons	2.56	2.49	2.54	2.53	88.3	85.0	56.7	76.7	73.3	73.8	72.6	73.2
Mean	2.38	2.29	2.24	2.30	85.5	82.8	34.7	67.7	74.1	74.5	71.5	73.4
Mean												
O.A.C. 21	2.26	2.25	2.17	2.22	72.0	75.2	13.4	53.5	73.6	73.9	68.8	72.1
Mensury	2.28	2.25	2.19	2.24	73.7	76.4	16.4	55.5	73.9	74.3	69.4	72.5
Gartons	2.63	2.53	2.66	2.61	74.4	76.1	47.9	66.1	72.2	73.0	71.4	72.2
Mean	2.39	2.34	2.34	2.36	73.4	75.9	25.9	58.4	73.2	73.7	69.9	72.3

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between varieties within dates Between dates within varieties	0.12	6.5	1.2
Between dates within stations Between stations within dates	0.04	3.7	0.5
Between varieties within stations Between stations within varieties	0.10	5.3	1.0
Between varieties within dates within stations	0.06	4.0	0.6

[5] The strain of Mensury used in this investigation was Mensury Ottawa 60.

TABLE 4.—DATA ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT, ILLUSTRATING INTERACTIONS BETWEEN VARIETIES, DATES OF SEEDING AND STATIONS, 1938 CROP

Variety	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Swan River	%	%	%	%	%	%	%	%	%	%	%	%
O.A.C. 21	1.99	2.01	2.10	2.03	93.8	77.1	43.6	71.5	75.8	74.1	71.4	73.8
Mensury	1.98	2.04	2.06	2.02	93.6	81.7	47.5	74.3	76.1	74.7	72.8	74.5
Gartons	2.20	2.24	2.42	2.28	94.0	89.9	69.1	84.3	75.9	74.9	73.3	74.7
Mean	2.06	2.10	2.19	2.11	93.8	82.9	53.3	76.7	75.9	74.6	72.5	74.3
Winnipeg												
O.A.C. 21	2.25	2.36	2.37	2.33	75.9	35.9	14.2	42.0	74.7	70.8	68.0	71.2
Mensury	2.31	2.34	2.36	2.33	78.0	34.6	7.6	40.1	74.6	71.2	67.6	71.1
Gartons	2.57	2.64	2.74	2.65	80.0	73.4	49.7	67.8	73.4	73.0	71.4	72.6
Mean	2.38	2.44	2.49	2.44	78.0	47.9	23.8	49.9	74.2	71.7	69.0	71.6
Newdale												
O.A.C. 21	2.43	2.27	2.47	2.39	43.9	10.3	16.9	23.7	73.1	71.2	70.4	71.6
Mensury	2.39	2.34	2.44	2.39	49.9	13.2	11.3	24.8	73.6	71.4	70.3	71.8
Gartons	3.04	3.15	3.21	3.13	51.3	45.0	58.0	51.4	70.6	69.8	69.4	69.9
Mean	2.62	2.59	2.70	2.64	48.4	22.8	28.7	33.3	72.4	70.8	70.0	71.1
Carman												
O.A.C. 21	2.44	2.55	2.65	2.55	63.0	51.0	9.3	41.1	72.9	71.3	63.8	69.3
Mensury	2.44	2.60	2.53	2.52	65.3	58.4	7.6	43.7	73.7	71.9	62.6	69.4
Gartons	2.69	2.89	2.94	2.84	74.0	77.2	42.3	64.5	72.8	73.0	70.0	71.9
Mean	2.52	2.68	2.71	2.64	67.5	62.0	19.7	49.8	73.1	72.1	65.5	70.2
Mean												
O.A.C. 21	2.28	2.30	2.40	2.32	69.2	43.6	21.0	44.6	74.1	71.8	68.4	71.5
Mensury	2.28	2.33	2.34	2.32	71.7	47.0	18.5	45.7	74.5	72.3	68.3	71.7
Gartons	2.62	2.73	2.82	2.73	74.8	71.4	54.8	67.0	73.2	72.7	71.1	72.3
Mean	2.39	2.45	2.52	2.46	71.9	54.0	31.4	52.4	73.9	72.3	69.3	71.8

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between varieties within dates Between dates within varieties	0.06	6.5	1.5
Between dates within stations Between stations within dates	0.06	4.6	0.8
Between varieties within stations Between stations within varieties	0.08	7.4	1.7
Between varieties within dates within stations	0.10	6.6	0.9

other varieties, as its decreases in quality were smaller. These differences account for the significant interaction between varieties and dates. It is also of interest to note that Gartons, though more stable than O.A.C. 21 or Mensury in reaction to dates of seeding in percentage heavy kernels, is less stable than they in nitrogen content.

While these differences in reaction between varieties are important in many ways, the absolute values for the malting properties for the three varieties are of greatest importance to the Canadian maltsters and to other purchasers of Canadian barley for malting. It is important to note that in 1937 only the barley from the first and second dates of seeding would be considered as malting barley. In 1938 only the barley from the first date of seeding would be classed as malting barley. In both years, for the dates from which malting barley was obtained, Gartons was inferior in malting quality to O.A.C. 21 and Mensury. The latter two varieties were similar in values for all properties as well as being similar in reaction. The reasons for faulting Gartons are fairly obvious; they are high barley nitrogen content and low malt extract. The wort nitrogen data in Table 1 bring out another fault in Gartons in that despite its much higher barley nitrogen content it is not proportionately higher than the other varieties in wort nitrogen content. This indicates a deficiency in protein modification in malt made from Gartons.

The interactions between date of seeding and stations shown in the analyses of variance are also illustrated in Tables 3 and 4. The 1937 results show that while seeding at the third date decreased quality at both stations, the extent of the decrease varied between stations. The effects of the delayed seeding were less marked at Carman than at Winnipeg. Changes in the effects of delayed seeding under different environments are also shown in the 1938 data. In this year, progressively later seeding caused progressive decreases in malt quality in general, but the rates of change differed at the different stations. Quite marked decreases in quality from the first to second date occurred at Winnipeg and Newdale, but the decreases were less marked at Swan River and Carman. There were also considerable differences between stations in the degree of change in quality from the second to the third date. At Carman the decrease was very great and at Newdale it was quite small. The degree of change at Winnipeg was greater than that at Swan River, but considerably less than the decrease at Carman.

These data indicate clearly that, although there are definite average decreases in quality due to delayed seeding, the degree of decrease varied according to environment. This is a similar type of differential to that observed in the reaction of varieties to changes in seeding date.

It was noted earlier that triple interactions existed between varieties, dates of seeding and stations. These are combinations of the simple interactions, and are not as important as the latter. Of the simple interactions, only that between varieties and stations has not been discussed. In general, this interaction is also caused by Gartons reacting differently from the other varieties, as is shown in Tables 3 and 4. Gartons appears less stable in nitrogen content than the other varieties, and when conditions are such that the general nitrogen level increases, the nitrogen content of

Gartons increases at a greater rate than those of the other varieties. Similarly, the varietal comparisons with respect to malt extract change from station to station in the 1938 crop, Gartons also being responsible for the differential. The triple interactions may thus be regarded as being caused by the differences in reaction between Gartons and the other varieties. With respect to percentage heavy kernels, inspection of Table 4 shows that, while on the average all varieties decreased progressively in this property with later seeding and Gartons showed less decrease than the other varieties, the latter varies in its behaviour from station to station. The results for malt extract show that in 1937 the triple interaction was caused by the difference between stations in the comparisons of O.A.C. 21 and Gartons at the first and third dates of seeding. At the first date, Gartons was more inferior to O.A.C. 21 at Winnipeg than at Carman, while at the third date Gartons was more superior to O.A.C. 21 at Winnipeg than at Carman. In the 1938 crop, on the average, Gartons was lower than the other varieties in extract at the first date, slightly higher than they at the second date, and definitely higher at the third date. The data for the individual stations in Table 4 show deviations from this average performance. At Swan River there was a close similarity throughout between the extracts for Mensury and Gartons, and at Newdale, Gartons was considerably lower than O.A.C. 21 and Mensury in extract. The extremely low extracts for the latter varieties at the third date are rather striking, but not surprising in view of the very low percentages of heavy grade barley.

The decrease in malting quality of barley due to delayed seeding is the most important aspect of the results of the two years' tests. Although the results for the two years, and for the different stations, do not show the same trends between the first and second dates of seeding, the decreases caused by delaying seeding to the third date are so great that there is no alternative but to conclude and recommend that early seeding is necessary for the production of malting barley. The differences between the two years in the effect of delaying seeding from the first to the second date may be interpreted to mean that the period for which seeding may be safely delayed without impairing malting quality varies between years. The data, representing only two years, provide no information bearing on the prediction of seasons or stations in which some delay in seeding date is safe. Accordingly, it seems best to recommend that malting barley be seeded as early in May as is possible.

Although the differences in reaction to date of seeding between Gartons and the other varieties are of interest, they are of no practical importance in the production of malting barley, though they do have some indirect interest to Canadian maltsters. Considering the means over all stations in each year, it is obvious that in 1937 only those barleys from the first and second dates of seeding were suitable for malting, and in 1938 only the barleys from the first date were suitable. Of the barley acceptable for malting, on the mean values, O.A.C. 21 and Mensury would be preferable to Gartons, owing to higher extract and lower nitrogen content. Irrespective of the smaller decrease in quality due to delayed seeding for Gartons than the other varieties, the fact remains that it was a decrease and the malt did not produce enough extract to satisfy commercial requirements.

Along with the decreased extract yield, the relatively high barley nitrogen content, which results in an excessive amount of wort nitrogen, is a further disqualifying factor for Gartons. The recommendation to seed barley for malting early may then be expanded by stating that among the three varieties tested O.A.C. 21 and Mensury are definitely superior to Gartons.

The differences in reaction between Gartons and the other varieties to changes in seeding date and in environment indicate differences between the varieties in physiological characters. These, being inherent in the variety, are likely to be evident in the malting process. This hypothesis is supported by the malting data. As noted previously, malting quality is ill defined, but some qualities which are not wanted are now well known. Gartons, even though at times higher in extract yield than O.A.C. 21 and Mensury grown under identical conditions (e.g. Gartons samples from the later seeding dates), was high in both barley and wort nitrogen content. Definition of optimum protein content has long been a problem in malting and brewing, but again it is established that high protein content is not wanted. The behaviour of Gartons on the malting floor and its protein balance in the wort have been under suspicion for some time. The lack of ease of kernel modification demonstrated by Gartons is typical of enzymatic deficiencies. Typical of these reactions of Gartons is its reaction to changes in environment with respect to barley nitrogen content. It was noted that in 1937 Gartons was closer to O.A.C. 21 in nitrogen content at Carman than at Winnipeg, and that the latter station produced barley of higher nitrogen content than the former. A similar general picture is seen in the 1938 data, in which, with increase in the general nitrogen level, the difference between O.A.C. 21 and Gartons in nitrogen content increased. That is, Gartons appeared more nearly similar to O.A.C. 21 in nitrogen content and malting quality when grown under low nitrogen conditions than when grown under high nitrogen conditions. The high nitrogen content of Gartons, its variability in nitrogen content, and other associated properties which impair wort quality, appear to be its outstanding faults. It thus appears that the dislike of the Canadian maltsters for Gartons is well justified.[6]

Effect of Rates of Seeding

The mean values, over all other factors, for each rate of seeding for each year, as given in Table 1, show that, on the average, variations in seeding rate had no effect on malting quality. The analyses of variance in Table 2 supplement this statement, and they also show that with respect to percentage heavy kernels, the interactions between varieties and rates of seeding, and the triple interactions between rates, dates and stations, were significant.

The interactions between varieties and rates of seeding may be traced to differences between Gartons and the other varieties, as shown in Table 5. O.A.C. 21 and Mensury were similar throughout, and show no significant or practical difference in percentage heavy kernels between seeding rates in either year. In both years, however, Gartons produced its highest percentage of heavy kernels from the light seeding rate.

[6] The Board of Grain Commissioners has ruled that after July 31, 1942, Gartons will not be eligible for grades higher than 3 C.W. Six Row.

TABLE 5.—DATA ON PERCENTAGE OF HEAVY KERNELS, ILLUSTRATING INTERACTIONS BETWEEN VARIETIES AND RATES OF SEEDING, 1937 AND 1938 CROPS

Variety	Heavy kernels—1937 crop				Heavy kernels—1938 crop			
	Rate 1	Rate 2	Rate 3	Mean	Rate 1	Rate 2	Rate 3	Mean
	%	%	%	%	%	%	%	%
O.A.C. 21	53.8	53.5	53.4	53.6	42.6	45.0	46.0	44.5
Mensury	54.5	54.6	57.5	55.5	44.5	47.0	45.5	45.7
Gartons	69.5	65.8	63.0	66.1	69.9	67.5	63.5	67.0
Mean	59.3	58.0	58.0	58.4	52.3	53.2	51.7	52.4

Necessary differences	1937	1938
Between rates within varieties Between varieties within rates	3.4	3.8

The triple interactions between rates, dates and stations are illustrated in Table 6. In 1937 at Winnipeg the light rate was highest in heavy kernels at the first two seeding dates, but lowest at the third date. At Carman there were no significant differences between rates of seeding at any date. The 1938 crop data are more complicated than those for the 1937 crop. Significant differences between rates may be noted at Swan River and Winnipeg only at the second date, at Newdale at the second and third dates, and at Carman at the first and second dates.

Over the two-year period the effects on the malting quality of the barley of differences in seeding rate are relatively small. The fact that interactions exist between varieties and rates of seeding is worthy of attention. It may be concluded that, in order to obtain the maximum percentage of heavy kernels, Gartons should be sown at a lighter rate of seeding than O.A.C. 21 and Mensury. The other differential response, while of some importance in the individual years at the different stations, does not provide information that can be used for defining the optimum rate of seeding for different dates at different stations. However, it is advisable to consider the dates of seeding from which malting barley was obtained and to determine whether differences between rates were significant.

Considering only the first two seeding dates in 1937, the light rate of seeding produced the best malting barley, followed closely by the medium rate at Winnipeg, while at Carman there was no real differences between the rates of seeding at these dates. The 1938 results show that there were no significant differences between rates of seeding at all stations with respect to malt extract at the first date, and only at Carman were there differences between rates with respect to percentage heavy kernels. At this station the medium rate of seeding was preferable. However, it may be noted that the heavy rate of seeding produced the highest nitrogen content, on the average, for which it may be faulted.

Differences in seeding rate therefore may be considered as not entirely without practical effect on the malting quality of barley. From these results the recommendation would be to sow malting barley, which should be sown early, at a light to medium rate of seeding.

While it appears that Gartons should be sown at a lighter rate than O.A.C. 21 or Mensury, this is of no special importance to producers of malting barley, who would be sowing O.A.C. 21 or Mensury, these being the only suitable malting varieties for Manitoba.

TABLE 6.—DATA ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT, ILLUSTRATING INTERACTIONS BETWEEN DATES OF SEEDING, RATES OF SEEDING AND STATIONS, 1937 CROP

	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
	%	%	%	%	%	%	%	%	%	%	%	%
Winnipeg												
Rate 1	2.32	2.43	2.45	2.41	66.0	73.2	14.8	51.4	73.0	72.9	67.6	71.2
2	2.39	2.38	2.40	2.39	58.5	69.3	16.1	48.0	72.2	73.0	68.2	71.2
3	2.46	2.37	2.43	2.42	59.3	64.4	20.1	47.9	72.0	72.9	68.9	71.3
Mean	2.40	2.39	2.43	2.41	61.3	69.0	17.0	49.1	72.5	72.9	68.2	71.2
Carman												
Rate 1	2.34	2.26	2.28	2.30	83.8	81.6	35.9	67.1	74.2	74.6	71.2	73.4
2	2.38	2.32	2.24	2.31	85.9	82.8	35.2	68.0	73.9	74.6	71.7	73.4
3	2.40	2.29	2.21	2.30	86.8	84.0	33.1	68.0	74.1	74.4	71.6	73.4
Mean	2.38	2.29	2.24	2.30	85.5	82.8	34.7	67.7	74.1	74.5	71.5	73.4
Mean												
Rate 1	2.34	2.35	2.37	2.35	74.9	77.4	25.4	59.2	73.6	73.8	69.4	72.3
2	2.39	2.35	2.32	2.35	72.2	76.1	25.6	58.0	73.1	73.8	70.0	72.3
3	2.43	2.33	2.32	2.36	73.0	74.2	26.6	58.0	73.0	73.6	70.3	72.3
Mean	2.38	2.34	2.34	2.35	73.4	75.9	25.9	58.4	73.2	73.7	69.9	72.3

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between dates within rates Between rates within dates	0.07	11.0	0.8
Between dates within stations Between stations within dates	0.04	3.7	0.5
Between rates within stations Between stations within rates	0.06	8.9	0.7
Between rates within dates within stations	—	4.0	—

TABLE 7.—DATA ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT, ILLUSTRATING INTERACTIONS BETWEEN DATES OF SEEDING, RATES OF SEEDING AND STATIONS, 1938 CROP

	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
	%	%	%	%	%	%	%	%	%	%	%	%
Swan River												
Rate 1	2.02	2.08	2.17	2.09	93.5	80.1	53.0	75.5	75.9	74.6	72.3	74.1
2	2.02	2.06	2.18	2.09	93.9	82.9	55.2	77.3	76.0	74.7	72.5	74.4
3	2.13	2.16	2.22	2.16	93.9	85.6	51.8	77.2	75.9	74.5	72.7	74.4
Mean	2.06	2.10	2.19	2.11	93.8	82.8	53.3	76.7	75.9	74.6	72.5	74.3
Winnipeg												
Rate 1	2.34	2.42	2.41	2.39	81.1	39.1	26.9	48.9	74.4	71.0	69.1	71.5
2	2.36	2.46	2.42	2.41	77.7	48.9	24.3	49.7	74.2	71.6	69.3	71.7
3	2.43	2.46	2.63	2.51	76.4	56.5	23.0	51.1	74.0	72.3	68.5	71.6
Mean	2.38	2.44	2.49	2.44	78.0	47.9	23.8	49.9	74.2	71.7	69.0	71.6
Newdale												
Rate 1	2.62	2.59	2.73	2.65	51.1	24.2	33.9	35.9	72.5	70.7	69.9	71.0
2	2.62	2.57	2.69	2.63	47.1	29.4	20.7	33.5	72.2	71.1	70.0	71.1
3	2.62	2.61	2.67	2.63	48.5	18.5	26.3	30.5	72.5	70.6	70.2	71.1
Mean	2.62	2.59	2.70	2.64	48.4	22.8	28.7	33.3	72.4	70.8	70.0	71.1
Carman												
Rate 1	2.49	2.70	2.72	2.64	65.0	58.7	23.0	48.9	73.0	72.0	65.4	70.1
2	2.53	2.67	2.70	2.63	72.2	66.2	18.1	52.2	73.2	72.4	65.5	70.4
3	2.55	2.67	2.70	2.64	65.1	61.7	18.0	48.3	73.2	72.0	65.5	70.2
Mean	2.52	2.68	2.71	2.64	67.5	62.0	19.7	49.8	73.1	72.1	65.5	70.2
Mean												
Rate 1	2.36	2.44	2.51	2.44	72.5	50.6	34.0	52.3	74.0	72.0	69.0	71.7
2	2.38	2.44	2.50	2.44	72.5	55.8	31.2	53.2	73.9	72.5	69.4	71.9
3	2.43	2.47	2.56	2.49	70.7	55.6	29.0	51.8	73.9	72.3	69.4	71.8
Mean	2.39	2.45	2.52	2.46	71.9	54.0	31.4	52.4	73.9	72.3	69.3	71.8

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between dates within rates Between rates within dates	0.06	5.5	0.6
Between dates within stations Between stations within dates	0.06	4.6	0.8
Between rates within stations Between stations within rates	0.07	6.3	0.6
Between rates within dates within stations	—	6.6	—

Effect of Rate of Fertilizer

The effects of fertilizer applications, on the average, as is shown in Table 1, had practically no influence on the malting quality of barley. However, these data, owing to the interactions evident in the analyses of variance, do not provide a complete picture of the effects of fertilizer treatments. Data showing the effect of fertilizer treatment on each variety have been summarized in Tables 8 and 9. These data present the mean difference between the fertilized and unfertilized barleys for each variety for the three major determinations. A negative sign indicates that the value for the fertilized barley was lower than that for the unfertilized barley, and absence of signs indicates that it was higher. It should be noted, from Table 1, that the two fertilizer applications are identical, for all practical purposes, in effect. These similarities were consistent throughout the experiments and for this reason no samples from the light rate of fertilizer for the 1938 crop were malted. In addition, it should be noted that in the tables showing the interactions between fertilizer and other factors, the values for the fertilized barleys for 1937 are the means over the two rates of fertilizer.

TABLE 8.—DATA* ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT SHOWING THE EFFECT OF FERTILIZER TREATMENT ON EACH VARIETY, AT EACH STATION AND AT EACH DATE, 1937 CROP

Variety	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
Winnipeg	%	%	%	%	%	%	%	%	%	%	%	%
O.A.C. 21	−.03	−.02	.02	−.01	−4.3	2.2	0.6	−0.5	−0.3	0	1.6	0.4
Mensury	.02	−.04	−.01	−.01	−4.1	3.0	4.7	1.2	−0.1	0.1	0.3	0.1
Gartons	.04	−.06	.08	.02	0.5	−3.4	−6.8	−3.2	−0.4	0.4	−0.8	−0.3
Mean	.01	−.04	.03	0	−2.6	0.6	−0.5	−0.8	−0.3	0.2	0.4	0.1
Carman												
O.A.C. 21	−.01	.08	−.01	.02	2.5	4.3	12.3	6.4	−0.2	−0.5	1.2	0.2
Mensury	.06	.05	−.01	.03	−0.3	2.1	9.3	3.8	−0.2	−0.1	1.2	0.2
Gartons	−.01	.04	−.03	0	1.3	1.6	1.4	1.4	0.2	0	0	0.1
Mean	.01	.06	−.02	.02	1.2	2.7	7.7	3.9	−0.1	−0.2	0.8	0.2
Mean												
O.A.C. 21	−.02	.02	0	0	−0.9	3.2	6.4	2.9	−0.2	−0.2	1.4	0.3
Mensury	.04	.01	−.01	.01	−2.2	2.5	7.0	2.4	−0.2	0	0.8	0.2
Gartons	.01	−.01	.02	.01	0.9	−0.9	−2.7	−0.9	−0.1	0.1	−0.4	−0.1
Mean	.01	.01	0	.01	−0.7	1.6	3.6	1.5	−0.2	0	0.6	0.1

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between stations	—	7.0	—
Between dates within stations } Between stations within dates }	—	4.0	—

* The data represent the value for the fertilized plot less the value for the unfertilized plot.

TABLE 9.—DATA* ON NITROGEN, HEAVY KERNELS AND MALT EXTRACT SHOWING THE EFFECT OF FERTILIZER TREATMENT ON EACH VARIETY, AT EACH STATION AND AT EACH DATE, 1938 CROP

Variety	Nitrogen				Heavy kernels				Extract			
	Date				Date				Date			
	1	2	3	Mean	1	2	3	Mean	1	2	3	Mean
	%	%	%	%	%	%	%	%	%	%	%	%
Swan River												
O.A.C. 21	−.01	.04	−.03	0	3.9	16.8	7.1	9.3	0.5	−0.1	1.5	0.6
Mensury	.04	.08	.07	.06	3.1	8.6	7.7	6.5	−0.2	−0.3	0.6	0.1
Gartons	.15	−.02	−.05	.03	0.8	2.3	−2.5	0.2	−0.2	−0.6	−0.1	−0.3
Mean	.06	.03	0	.03	2.6	9.3	4.1	5.3	0.1	−0.3	0.6	0.1
Winnipeg												
O.A.C. 21	.03	−.09	.03	−.01	3.0	−2.1	1.0	0.6	0.4	−0.1	0	0.1
Mensury	0	.02	−.05	−.01	3.2	−1.0	−1.3	0.3	0.2	−0.5	−0.5	−0.3
Gartons	.06	.03	.07	.05	−3.0	−6.5	1.9	−2.6	−0.3	−1.2	−0.2	−0.5
Mean	.03	−.01	.01	.01	1.1	−3.2	0.5	−0.5	0.1	−0.6	−0.2	−0.3
Newdale												
O.A.C. 21	−.03	.08	.02	.02	12.7	0.6	5.4	6.2	0.3	−0.2	0.5	0.2
Mensury	−.05	.02	.03	0	15.7	5.0	4.9	8.6	0.8	−0.1	0.1	0.3
Gartons	−.03	.06	−.04	0	4.8	−0.2	1.4	2.0	0	−0.6	0.1	−0.2
Mean	−.04	.05	.01	.01	11.1	1.9	3.9	5.6	0.4	−0.3	0.2	0.1
Carman												
O.A.C. 21	.15	.02	0	.06	28.0	16.4	0	14.8	0	0.5	3.9	1.4
Mensury	.16	.03	.10	.10	27.8	13.9	8.5	16.7	1.0	0.5	4.7	2.0
Gartons	0	−.10	−.07	−.05	−10.2	−5.6	13.1	−1.0	−0.9	0.2	0.7	−0.1
Mean	.11	−.01	.01	.04	15.2	8.2	7.2	10.2	0	0.4	3.1	1.1
Mean												
O.A.C. 21	.04	.01	.01	.02	11.9	8.0	3.4	7.7	0.3	0	1.4	0.6
Mensury	.04	.04	.03	.0	12.4	6.7	4.9	8.0	0.4	−0.1	1.2	0.6
Gartons	.05	0	−.03	.01	−1.9	−2.5	3.5	−0.4	−0.3	−0.4	0	−0.2
Mean	.04	.02	0	.02	7.5	4.0	4.0	5.1	0.1	−0.2	0.9	0.3

Necessary differences	Nitrogen	Heavy kernels	Extract
	%	%	%
Between varieties	—	2.8	0.4
Between dates	—	—	1.0
Between stations	—	5.4	1.1
Between dates within stations / Between stations within dates	—	5.4	0.7

* The data represent the value for the fertilized plot less the value for the unfertilized plot.

The 1938 data, in Table 9, show clearly that Gartons was reduced in percentage heavy kernels and malt extract due to fertilizer, while O.A.C. 21 and Mensury showed increases in those properties. These results cause the mean squares for $V \times F$ in Table 2 to be significant. In other words, fertilizer was beneficial to the malting quality of O.A.C. 21 and Mensury and not beneficial to Gartons. The 1937 crop data in Table 8 show the same tendencies, though the interaction mean squares do not attain the 5% level of significance.

The triple interaction between fertilizers, dates of seeding and stations, attains significance only for malt extract for the 1938 crop samples. Tracing out the simple interactions contributing to this interaction, it may be seen in Table 2 that the mean square for $D \times S$ is significant and the mean squares for $F \times S$ and $F \times D$ are of large magnitude. The interaction between dates and stations has been discussed previously, and Table 9 shows that fertilizer improved malt extract considerably at Carman had practically no effect at Swan River and Newdale, but tended to depress extract at Winnipeg. The differences between dates in effect of fertilizer are also considerable, with small effects at the first and second dates, but considerable improvement due to fertilizer may be noted at the third date. The triple interaction is therefore a combination of these simple differentials. Table 9 shows that at Swan River and Carman fertilizer produced its greatest effect at the third date and that the effect was beneficial. Fertilizer was also beneficial at Newdale in its greatest effect, which, occurred at the first date, while at Winnipeg the greatest effect of fertilizer was at the second date and it caused a decrease in extract.

The effect of fertilizer on yield per acre of barley is of first consideration to growers; the effect of fertilizer on quality is secondary and probably depends on effects on yield. The results with respect to the effects of fertilizer on yield per acre have been reported (8) and the two effects, on yield and on quality, will be compared and discussed in a later paper in which all aspects of the experiment will be summarized. From the malting data it may be concluded that on the average the application of fertilizer had no marked effects on the quality of barley. This is only a generalization, and it is perhaps not sufficiently positive to be of great value. It is known that by application of fertilizer in some areas yields may be increased, but there have been some fears that fertilizer reduced the quality of the barley. Stating that, on the basis of these tests in which fertilizer was applied to summer fallow, fertilizer had no appreciable effect on quality, may alleviate these fears. It should be noted, however, that the varieties reacted differently to fertilizer treatment. O.A.C. 21 and Mensury tended to improve in quality, on the average, with the application of fertilizer, while Gartons responded unfavourably. Accordingly, fertilizer applications can be recommended for O.A.C. 21 and Mensury but not for Gartons. It should be borne in mind, however, that fertilizer is not usually applied solely in order to improve crop quality and is not recommended for all areas.

It should be noted, in examining the effect of fertilizer, that malting quality is not definable in terms of any one property. On the average, fertilizer tended to increase nitrogen content. However, with O.A.C. 21 and Mensury, fertilizer also increased percentage of heavy grade kernels

to a greater extent than it affected nitrogen content, so that the total effect was to increase the malt extract of these two varieties. With Gartons the percentage of heavy grade kernels was reduced by fertilization, and the total effect was to reduce malt extract. The effect of fertilizer, as measured by nitrogen content alone, may therefore lead to erroneous conclusions if measurements on other properties are not carried out also.

Differences between dates, with respect to the effect of fertilizer, may be reasonably expected owing to differences in seasonal distribution of rainfall and available nutrients, and these differences were obtained in the experiments. The differences between years in fertilizer-date reaction may be largely attributed to differences between years in distribution of rainfall as well as in total rainfall. The effect on yield of grain may also have had some part in determining the effect on quality, and as noted before, this will be discussed in a later paper.

The differences between stations with respect to fertilizer are quite small at the first date of seeding, but increase with later dates. Bearing in mind differences between stations in soil moisture, in depletion of soil nutrients, and in rainfall, differences would be expected between them in effect of fertilizer. These, as noted earlier, may well vary with dates due to differences in seasonal distribution of rainfall.

The more complex interactions observed between fertilizer and other factors may be largely attributed to differences in the response of Gartons and the other two varieties to fertilizer, to the differences between dates with respect to effect of fertilizer, and to the relatively unfavourable response to fertilizer at Winnipeg. They are thus combinations of simple interactions and are of no great importance in themselves as complex differentials.

In earlier discussions it was shown that barley suitable for malting was obtained only from plots seeded on the first two dates in 1937 and only from plots seeded on the first date in 1938, except at Swan River where barley from plots seeded on the second date was also suitable for malting. It thus seems reasonable to consider the effect of fertilizer in terms of its effects on samples seeded at the dates given in the previous sentence, i.e., on samples suitable for malting. In 1937 at both stations the effects of fertilizer were comparatively small when considering only the first two seeding dates. Though there was some reduction in extract due to fertilizer, the effect would not be considered serious enough to fault the barleys to any marked extent, and the real value of the fertilizer would be determined by its effect on grain yield. In general the same is true in the 1938 data when considering only the dates from which malting barley was obtained. There was a tendency towards lowered extract due to fertilizer at Swan River, but the decrease was not serious. At the other three stations, at which only barley from plots seeded on the first date was malting barley, fertilizer produced generally beneficial results. In general, however, Gartons did not respond as well to fertilizer as did O.A.C. 21 and Mensury. It may then be concluded that fertilizer as applied in this study did not seriously affect the quality of malting barley in any way. It was somewhat beneficial to O.A.C. 21 and Mensury, but it did not increase the quality of late-sown barley to the point at which it would be considered suitable for malting.

CONCLUSIONS

Differences between Canadian varieties in malting quality have been recognized (1, 6) and have been the basis of detailed study in Canada (3, 5, and other papers in the series) for several years. There is thus ample evidence to show that in the production of malting barley the selection of a suitable variety is of first importance. It is also important to note that the results of all these tests show that Gartons, which has been graded as malting barley, is not equal in quality to O.A.C. 21, the standard malting variety, when compared with it under identical conditions which favour the production of good malting barley. Suitable varieties for the production of malting barley in Manitoba are therefore O.A.C. 21 and Mensury.

The date of seeding of barley plays a decisive role in determining the quality of the crop, as well as determining the yield (7), and early seeding is necessary for the production of high class malting barley. Delayed seeding reduced the quality of all varieties, and though the varieties reacted differently to changes in seeding date, Gartons' reduction in quality being less than those for the other varieties, it appears quite definite that malting barley cannot be produced by late seeding methods. If late seeding is practised, the chances of producing malting barley, for which a premium is paid, are forfeited.

Rates of seeding did not play any great part in these experiments in influencing malting quality. However, light to medium rates of seeding appear to be preferable to a heavy rate for the production of malting barley.

The application of fertilizers did not affect the malting quality of the barleys to any great extent. There were interesting interactions between fertilizer and other factors, but they are important in the widest aspects of barley cultivation rather than in the production of malting barley. Fertilizer is rarely applied as an improver of quality, particularly in grain crops, and its choice is dependent on locality and probable effect on yield. However, the results do throw some light on the subject of fertilizer application. In general, fertilizer had no great effect on malting quality, so long as other conditions favoured the production of good malting barley. There were differences between stations with respect to effect of fertilizer, but these were by no means unexpected and are probably related to the effect of fertilizer on yield. The differential response of the varieties to fertilizer with respect to malting quality are of interest in further emphasizing the difference between Gartons and the other varieties. These reactions are also similar to those noted in respect to yield (8). The comparison of the agronomic and malting results, as noted previously, will be discussed in a later paper.

It may be concluded then that in the production of malting barley, the farmer in Manitoba is very limited in choice of methods of culture, but at the same time the limitations imposed are not greater than those in any system of husbandry devoted to quality production. For malting barley, O.A.C. 21 or Mensury should be sown early, at a light to medium rate of seeding. The decision as to fertilizer may be made according to locality, season and general experience with fertilizer as affecting yield of grain.

SUMMARY

The results of malting tests made on samples representing three varieties of barley, O.A.C. 21, Mensury and Gartons, obtained from tests made to determine the effect of cultural practices on the yield of barley are discussed. The cultural practices studied were dates of seeding, rates of seeding and fertilizer treatments. Three levels of dates, rates of seeding and rates of fertilizer were studied simultaneously with the three varieties in factorial combination. The tests were carried out on samples representing two years, 1937 and 1938. Two stations were represented in 1937 and four in 1938.

O.A.C. 21 and Mensury were equal in malting quality and similar in all reactions. Gartons was inferior to these varieties as malting barley and differed from them in reaction to changes in cultural practices. Gartons was faulted in barley nitrogen content, malt extract and wort nitrogen content. During the malting process it failed to develop the degree of modification shown by O.A.C. 21 and Mensury.

Date of seeding was an important factor determining malt quality and only the barley grown at the first date, early in May, would be suitable for admission to the malting grades. Gartons was less affected by delayed seeding than either O.A.C. 21 or Mensury, but also suffered appreciably in quality.

On the average, differences in rate of seeding did not influence malting quality to any great extent, but a light to medium rate of seeding appears preferable to a heavy rate. Gartons favoured a lighter rate of seeding than did O.A.C. 21 and Mensury.

The application of fertilizer had no marked effect on malting quality. There was a slight increase in nitrogen content due to fertilizer, but this was more than counterbalanced in O.A.C. 21 and Mensury by increases in percentages of heavy grade barley. This latter effect was not shown in Gartons. The response to fertilizer also varied between stations, between dates of seeding and between years. These conditions no doubt reflect other differing environmental conditions. On the whole, however, with the barleys that could be considered suitable for malting, fertilizer did not decrease malting quality.

It is concluded that for the production of malting barley in Manitoba, O.A.C. 21 and Mensury should be sown early at a medium rate of seeding. Fertilizer requirements will depend on locality.

ACKNOWLEDGMENTS

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REFERENCES

1. Anderson, J. A. and H. Rowland. Studies on malting quality I. 1935 Variety trials. Sci. Agr. 17 : 593-600. 1937.

2. Anderson, J. A. and H. Rowland. Modified equipment and methods for the routine malting test and a study of its precision. Sci. Agr. 17 : 742-751. 1937.

3. Anderson, J. A., H. R. Sallans and C. A. Ayre. Varietal differences in barleys and malts III. Correlations between nitrogen and saccharifying activities. Can. J. Research, C, 16 : 456-466. 1938.

4. Goulden, C. H. Methods of Statistical Analysis. John Wiley & Sons, New York. 1939.

5. Meredith, W. O. S. and J. A. Anderson. Varietal differences in barleys and malts IV. Commonly measured properties and their correlations with nitrogen and 1,000 kernel weight. Can. J. Research, C, 16 : 497-509. 1938.

6. Meredith, W. O. S., H. Rowland and J. A. Anderson. Malting quality of Canadian barleys II. Nineteen varieties, 1936 and 1937 trials. Sci. Agr. 19 : 389-403. 1939.

7. Olson, P. J., W. O. S. Meredith, H. C. Laidlaw and A. J. Lejeune. Cultural studies with barley I. Differential responses of varieties to date of seeding with respect to yield. Sci. Agr. 22 : 225-241. 1941.

8. Olson, P. J., W. O. S. Meredith, H. C. Laidlaw and A. J. Lejeune. Cultural studies with barley II. Differential responses to fertilizer treatment and rate of seeding with respect to yield. Sci. Agr. 22 : 659-673. 1942.

MEASUREMENT OF WIND EROSIVENESS OF SOILS BY DRY SIEVING PROCEDURE[1]

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In a previous paper (1) a description was given of the experiments conducted in a wind tunnel on the erosiveness of a soil as governed by its dry aggregate composition. It was found that the erosiveness q over a level surface under a 17-m.p.h. wind, measured at 1-foot height, should be given by the formula

$$q \text{ (17 m.p.h.)} = \text{antilog}\left[\frac{0.60\,S + 1.02\,T + 1.40\,U + 1.74\,V}{S + T + U + V} - \left(0.30\,\frac{C}{C+D+E+F}\,\frac{B}{A+B}\right) - \left(0.96\,\frac{D+E+F}{C+D+E+F}\,\frac{B}{A+B}\right) - W - X - Y - Z\right] \qquad (1)$$

where A = per cent erosible fractions < 0.42 mm. in diameter,
B = per cent erosible fractions 0.42–0.83 mm. in diameter,
C = per cent non-erosible fractions 0.83–2.0 mm. in diameter,
D = per cent non-erosible fractions 2.0–6.4 mm. in diameter,
E = per cent non-erosible fractions 6.4–12.7 mm. in diameter,
F = per cent non-erosible fractions > 12.7 mm. in diameter,
$S = 0.052\,C$, $T = 0.048\,D$, $U = 0.045\,E$, $V = 0.041\,F$,

$$W = 5.2\,\frac{C}{A+B+C},$$

$$X = 4.8\,\frac{D}{A+B+C+D},$$

$$Y = 4.5\,\frac{E}{A+B+C+D+E},$$

$$Z = 4.1\,\frac{F}{A+B+C+D+E+F},$$

q = the amount of erosible soil in kilograms per square metre of exposed surface.

Under a 22-m.p.h. wind erosiveness should be expressed by

$$q = \text{(22 m.p.h.)} = \text{antilog}\left[\frac{0.86\,S + 1.23\,T + 1.57\,U + 1.85\,V}{S + T + U + V} + \left(0.42\,\frac{C}{C+D+E+F}\,\frac{B}{A+B}\right) - \left(0.76\,\frac{D+E+F}{C+D+E+F}\,\frac{B}{A+B}\right) - W - X - Y - Z\right] \qquad (2)$$

[1] Contribution from the Experimental Farms Service (P.F.R.A.), Dominion Department of Agriculture, Ottawa.
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where $S = 0.041\, C$, T $= 0.039\, D$, $U = 0.037\, E$, $V = 0.035\, F$, and

$$W = 4.1 \frac{C}{A + B + C},$$

$$X = 3.9 \frac{D}{A + B + C + D},$$

$$Y = 3.7 \frac{E}{A + B + C + D + E},$$

$$Z = 3.5 \frac{F}{A + B + C + D + E + F}.$$

A formula was also given for a 30-m.p.h. wind, but such high velocity as this is rare in nature and will therefore not be considered in this paper.

An attempt was made to use the formulae for determining the relative erosiveness of different soils, but they were found too laborious to be applied on any extensive scale. Their complicated nature arose from the fact that erosion is affected by a multiple number of variable factors, but the inclusion of the effect of these factors reduced the value for which they were intended, namely, to serve as a measure of erosiveness of any sample of soil as revealed by its dry aggregate composition.

In order to derive a practical method an attempt was made to simplify the formulae without appreciably reducing their accuracy. It is the purpose of this paper to present this simplified method and to show the degree of accuracy and feasibility of the dry sieving technique as a measure of wind erosiveness of cultivated soils.

METHOD OF PROCEDURE

The erosiveness of different soils was determined by exposure to wind in a return-flow type wind tunnel already described (1). The soils were exposed to wind in a trough 6 feet long, 6 inches wide, with open ends, placed parallel to the direction of the wind. The soil surface was levelled with a straightedge. Some differences in the degree of roughness of surface existed on different samples but these were due to differences in the size of clods and not to differences in the treatment.

For all soils there was no available velocity at which erosion continued indefinitely. The erosion was intense at the start but decreased rapidly at first and less and less rapidly with continued exposure and ceased as soon as the surface became stabilized with aggregates too coarse to be moved by the wind. The quantity of soil eroded up to the time when movement ceased constituted one type of measurement of erosiveness. This measurement represents the total quantity of soil erosible under a definite wind velocity. The time required for movement to cease varied considerably with soil structure and wind velocity, the range being approximately from 15 to 60 minutes.

In later experiments the soil was exposed to a 17-m.p.h. wind for 3 minutes and then to a 22-m.p.h. wind for the same length of period, the amount eroded under both velocities being regarded as a relative measure of erosiveness. It has been shown previously (2) that over the same type

of surface and equal wind velocity, the quantity eroded during 3 minutes and the total quantity of erosible soil vary more or less proportionately, so that either measurement may be used to indicate the relative erosiveness of a soil.

Clod structure was determined by sieving only after the soils became thoroughly air-dried. Replicated 1,000-gram samples were used for analysis. A nest of sieves with square openings ranging from 0.42 to 38 millemeters was used. An equal amount of shaking of all the sieves was found to give erroneous results because the coarser sieves required less shaking than the finer ones. The nest of sieves was therefore, shaken until all clods smaller than the largest sieve opening appeared to have passed through. The upper sieve with its contents was then removed and the same procedure repeated. Special care was taken to prevent clogging of the finer sieves. The same vigour of shaking was given on all samples analyzed. To avoid possible inconsistencies in treatment one person carried out the analyses on any one group of comparable soils.

SIMPLIFICATION OF EROSION FORMULAE

Formulae 1 and 2 indicate that the amount of reduction of the logarithm of erosiveness caused by each unit of the non-erosible fractions C, D, E and F varies somewhat with the size of the fractions and wind velocity. The differences in the amount of reduction due to differences in the size of the non-erosible fractions are not very great, however, and may be discounted without greatly impairing the accuracy of the formula. Thus, the replacement of the first part

$$\frac{0.60\,S+1.02\,T+1.40\,U+1.74\,V}{S+T+U+V} \text{ by } \frac{0.60\,C+1.02\,D+1.40\,E+1.74\,F}{C+D+E+F}$$

and

$$\frac{0.86\,S+1.23\,T+1.57\,U+1.85\,V}{S+T+U+V} \text{ by } \frac{0.86\,C+1.23\,D+1.57\,E+1.85\,F}{C+D+E+F}$$

does not greatly alter the original values, but simplifies the computation somewhat. Likewise, the replacement of $W + X + Y + Z$ by $0.05\,(C + D + E + F)$ for a 17-m.p.h. wind and by $0.04\,(C + D + E + F)$ for a 22-m.p.h. wind gives values not appreciably divergent from the original.

The effect of fraction B under a 17-m.p.h. wind is shown to vary somewhat depending on the relative proportion of fractions A, C, D, E, and F. When the erosible fraction A in mixture with C is replaced entirely by the less erosible fraction B, the logarithm of erosiveness, as can be observed from formula 1, is reduced by 0.30, but when A is mixed with any one or all of the fractions D, E and F, its replacement by B lowers the logarithm of erosiveness by 0.96, while a partial replacement of A by B decreases the logarithm of erosiveness proportionate to the amount replaced. Actually, the variations produced by fraction C on the one hand, and D, E, F on the other, are not very appreciable, hence, it may be assumed

that the replacement of A by B lowers the logarithmic value by approximately 0.6 irrespective of the proportion of fractions C, D, E and F present in a mixture. Accordingly, the portion of the formula expressed by

$$\left(0.30 \; \frac{C}{C+D+E+F} \; \frac{B}{A+B}\right) + \left(0.96 \; \frac{D+E+F}{C+D+E+F} \; \frac{B}{A+B}\right)$$

may be replaced to considerable advantage by $0.6 \; \frac{B}{A+B}$. Under a 22-m.p.h. wind, on the other hand, the differences produced by the same factors appear to be too great to be ignored, hence their individual influences will have to remain as indicated in the original formula for that particular velocity.

Formulae 1 and 2 may now be reduced to much simpler form as follows:

$$q \text{ (17 m.p.h.)} = \text{antilog} \left[\frac{0.60\,C + 1.02\,D + 1.40\,E + 1.74\,F}{C+D+E+F} - 0.6\,\frac{B}{A+B} - 0.05\,(C+D+E+F)\right] \ldots\ldots (3)$$

and

$$q \text{ (22 m.p.h.)} = \text{antilog} \left[\frac{0.86\,C + 1.23\,D + 1.57\,E + 1.85\,F}{C+D+E+F} + 0.42\left(\frac{C}{C+D+E+F}\,\frac{B}{A+B}\right) - \left(0.76\,\frac{D+E+F}{C+D+E+F}\,\frac{B}{A+B}\right) - 0.04\,(C+D+E+F)\right] \ldots\ldots (4)$$

An attempt was further made to work out a general formula that would give an approximate measure of erosiveness for the whole range of the usual erosive velocity, that is, up to 25 m.p.h. at a 12-inch height. This was accomplished by converting the logarithmic values in formulae 3 and 4 to numerical, then averaging and converting the numerical back to logarithmic terms. The expression so determined transposes to

$$q = \text{antilog} \left[\frac{0.75\,C + 1.14\,D + 1.49\,E + 1.80\,F}{C+D+E+F} - 0.6\,\frac{D+E+F}{C+D+E+F}\,\frac{B}{A+B} - 0.042\,(C+D+E+F)\right] \ldots\ldots (5)$$

Observations showed that erosion, which included the movement of soil particles up to 0.8 mm. in diameter, either in the field or a tunnel, began over a level surface when the wind reached a velocity of 13 to 15 15 m.p.h. at one foot height. The most common erosive velocity was observed to vary between 17 and 22 m.p.h. and only on rare occasions reaching that of 25 m.p.h. It can therefore be assumed that formula 5 denotes an approximate average effect of the usual range of natural erosive velocity.

COMPARISON OF DETERMINED WITH COMPUTED ORDER OF EROSIVENESS

A comparison of the quantities of soil eroded in the wind tunnel with those based on the dry sieving analysis and computed according to formula 5 can be made from examination of the data in Table 1. The soils shown in Table 1 were collected from the provinces of Manitoba, Saskatchewan, and Alberta and vary widely with respect to erosiveness by wind. There is, on the whole, a fair agreement between the order of determined and computed erosiveness. The actual differences between the corresponding erosion values, however, are due to the fact that they are a measure of the two actually different things which, though different in magnitude, vary directly with each other. The determined erosiveness is based on the weight of the soil removed during 3 minutes under a 17-m.p.h. wind and during the same length of period under a 22-m.p.h. wind. The computed erosiveness, on the other hand, is based on the total amount of soil erosible under these two velocities. The amount of soil removed during 6 minutes of exposure does not represent the total erosible soil but merely denotes the relative intensity of erosion for that period. Provided the roughness of the soil surface is the same, the initial intensity of erosion and the total quantity of erosible soil vary directly with each other, so that one or the other could serve as a measure of erosiveness. For different degrees of roughness of surface, however, the 3-minute exposures on the 6-foot length of the exposed soil gave a more accurate measure of erosiveness (2) than exposure for the length of time required for erosion to cease. The intensity of erosion, as measured by the rate of soil flow, is the determining factor.

The values of actual and computed erosiveness were plotted on a graph as shown in Figure 1 and the regression of amount eroded on computed erosiveness was estimated by the method of least squares. The average increase of the amount eroded for each unit increase of computed erosiveness, known as regression coefficient, was found to be 0.288 and the standard error of the regression coefficient 0.01. The regression coefficient divided by its standard error gives a quotient of approximately 29, which for 27 degrees of freedom is away above the level of significance. The evidence of a relation between the amount of eroded soil and computed erosiveness is very conclusive. The data indicate that formula 5 can be employed as an approximate relative measure of wind erosiveness of

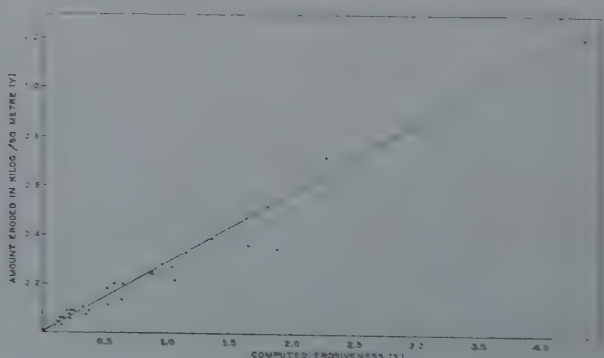

FIGURE 1. Regressiveness of amount eroded on computed erosiveness.

TABLE 1.—RELATION BETWEEN THE DRY CLOD STRUCTURE AND WIND EROSIVENESS OF SOILS

Soil Type	Size distribution of dry clods in %						Computed erosiveness	Amount eroded in 6 minutes
	>1.27 mm.	12.7–6.4	6.4–2.0	2.0–0.83	0.83–0.42	<0.42 mm.		
	(F)	(E)	(D)	(C)	(B)	(A)	(X)	(Y)
Almasippi fine sandy loam	1.0	2.7	4.9	3.6	5.1	82.7	4.19	1.31
Souris fine sandy loam	2.0	3.1	4.6	3.5	5.7	81.1	4.27	1.21
Hatton fine sandy loam	8.1	4.8	5.7	4.2	8.2	69.0	2.30	0.72
Sceptre clay	2.0	3.9	6.0	9.0	18.6	60.5	1.38	0.39
Altona fine sandy loam	5.5	5.4	8.0	5.5	5.4	70.2	1.68	0.36
Asquith fine sandy loam	7.1	4.6	7.3	4.8	6.8	69.4	1.90	0.35
Regina heavy clay	1.2	3.2	5.9	8.7	35.9	45.1	1.16	0.33
Sceptre heavy clay	2.5	4.8	7.4	8.9	28.8	47.6	0.99	0.28
Fine sandy loam (Claresholm, Alta.)	8.2	8.5	8.5	5.6	7.8	61.4	1.06	0.27
Waskada clay loam	10.8	4.3	7.2	7.3	11.7	58.7	1.09	0.22
Manitou clay loam	6.2	4.1	9.7	10.8	24.8	44.2	0.58	0.20
Fine sandy loam (Medicine Hat, Alta.)	21.3	4.8	7.0	5.8	9.2	51.9	0.65	0.20
Oxbow loam	14.4	10.7	6.8	6.6	12.7	48.8	0.51	0.18
Haverhill light loam	9.4	9.2	8.2	7.6	11.3	54.3	0.64	0.13
Fox Valley silty clay loam	14.0	7.2	9.4	6.9	11.8	50.7	0.52	0.11
Melfort silty clay loam	3.9	3.4	11.4	15.8	19.6	45.9	0.33	0.10
Heavy clay (Drumheller, Alta.)	2.0	6.1	10.0	17.1	34.6	30.2	0.26	0.09
Loam (Parkland, Alta.)	18.6	6.8	8.6	7.4	12.2	46.4	0.38	0.09
Silt loam (Nobleford, Alta.)	15.2	9.0	9.8	11.8	12.0	42.2	0.20	0.09
Loam (Sibbald, Alta.)	17.6	8.2	11.2	8.9	13.2	40.9	0.22	0.09
Weyburn loam	25.0	6.8	8.9	7.6	10.6	41.1	0.22	0.08
Haverhill loam	20.5	7.4	8.0	7.1	12.1	44.9	0.35	0.07
Clay loam (Kipp, Alta.)	8.8	8.6	12.6	13.4	20.0	36.6	0.18	0.06
Haverhill clay loam	20.8	8.2	8.8	8.1	14.3	39.8	0.23	0.06
Elstow silt loam	23.4	9.4	10.6	7.3	9.2	40.1	0.17	0.06
Loam (Medicine Hat, Alta.)	29.2	7.2	9.0	8.2	11.8	34.6	0.13	0.04
Silt loam (Bow Island, Alta.)	30.8	7.0	7.9	7.4	11.9	35.0	0.14	0.03
Elstow silty clay loam	25.5	8.6	10.7	9.6	13.9	31.7	0.10	0.03
Red River clay	8.7	10.3	13.7	29.7	24.3	13.3	0.02	T
Val Marie clay	15.5	17.0	23.8	23.3	12.3	8.1	T	T

freshly cultivated and uniformly mixed soils. The highly erosive soils were observed to have an erosion value greater than 1, whereas the resistant to moderately erosive soils had an erosion value of less than 1.

The computed erosion values in Table 1 do not necessarily represent the average erosiveness of the different soil types, but merely the erosiveness of a particular sample at the time the analysis was made. The differences in the tillage treatment previous to sampling may have caused profound differences in the actual erosiveness of the different soils. The differences in erosiveness of clay and loam soils, for example, are greatest in the early spring and least following heavy summer rains, whereas the differences between loams and sandy loams are more or less the same all the year around. In spite of the probable effect of these factors the computed erosiveness of most soils in Table 1 coincides quite well with the generally observed order of erosiveness in the field.

The possible errors due to the differences in the apparent specific gravity of the different soils are apparently not very great. Variations in the apparent specific gravity of the non-erosible clods are of course not important, for the degree to which they protect the soil is determined entirely by their shape and size. An increase in the apparent specific gravity of the erosive fractions may be expected to cause a decrease in the volume of removed soil, but that may be somewhat counterbalanced by the increased weight of the material removed.

The general erosion formula applies to soils that have been recently cultivated and in which the various sizes of dry clods and fine erosive fractions are mixed uniformly. It can hardly be expected to apply to soils that have been left untilled for some time or have otherwise been allowed to form a surface crust following a rain. Wind erosion is dependent on the physical soil characteristics at the very surface, which in an untilled condition may be entirely different in structure from soil even a few millimeters below.

The dry sieving procedure appears to afford an approximate measure of erosiveness, but errors may arise by virtue of the fact that similar sizes of aggregates, especially the larger sizes, have a tendency to segregate. Extreme care must therefore be taken to see that the sample taken for dry sieving analysis represents the average of the whole. Since results of dry sieving analysis vary somewhat depending on the vigour and the amount of shaking, it is imperative that a definite procedure be followed on all comparable soils. The simplified general formula, as presented, is practical enough to be used extensively, but its reduced complexity makes it somewhat less accurate, particularly for the less common structural conditions of the soil.

SUMMARY

A method of determining the approximate wind erosiveness of freshly cultivated soils is described. The method is based on wind tunnel experiments showing the relation between erosiveness and the dry aggregate structure as determined by dry sieving procedure.

REFERENCES

1. Chepil, W. S. Relation of wind erosion to the dry aggregate structure of a soil. Sci. Agr. 21 : 488-507. 1941.
2. Chepil, W. S. and R. A. Milne. Wind erosion of soil in relation to roughness of surface. Soil Sci. 52 : 417-433. 1941.

A STUDY OF THE NUTRITIONAL VALUE OF WHEAT GERM PRODUCTS FOR SWINE. II[1]

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Search of the literature reveals a dearth of information on the nutritional properties of the germ fraction of cereal grains. It has long been known, of course, that vitamin E is abundant in wheat germ and wheat germ oil; and also that the bran coating of rice and of wheat are rich in "water soluble B." There is also but meagre information concerning any other nutrients of the germs of cereals, and what there is reveals nothing of special importance which could explain the rather striking effects which the germ fractions have in certain animal diets.

For example, swine feeding tests now in progress at Macdonald College show that much of the growth promoting and fattening properties of diets composed of a cereal grain suitably fortified with proteins, minerals and vitamins A and D, is lost when the germ of the grain is removed. Also a markedly greater improvement in the ration was obtained by adding wheat germ to any of the degermed cereals than by corn germ supplement. In these tests replacing the germ of any of these degermed cereals with wheat germ resulted in the highest rates of gain obtained in the test.

What factors in wheat germ are responsible for this "growth effect" are as yet not clearly established. This feed fraction contains most of the fat of the wheat berry, and presumably this portion will contain any and all of the fat soluble vitamins present. Vitamin E is the only one of these entities usually recognized, though Boas-Fixsen and Roscoe (1) list wheat germ to contain 650 I.U. vitamin A per 100 grams germ. This would be about 4,500 I.U. per 100 grams of wheat germ oil if it is all in the fat fraction, and none lost or destroyed during the fat extraction.

The non-fat fraction of wheat germ is accepted by the Council on Foods of the American Medical Association (2) as a rich source of B_1 (about 730 I.U. per 100 grams germ), and a fair source of G (riboflavin). Its phosphorus content though high is not an important supplementary source in normal rations, perhaps because it is largely in phytin combination. Two other members of the vitamin B family are known to be present (B_6, pyrodoxine and nicotinic acid) but their amounts, as with thiamin and riboflavin, are highly variable according to sample. There is some evidence for the presence of inosotol (anti-alopica factor) in wheat germ but since this is a phytin compound, it may not be available to some classes of animals.

In 1940, a series of trials was started at Macdonald College designed to obtain more information on the nutritive properties of wheat germ. Specifically, it was desired to learn whether or not additions of the oil or of the defatted fraction to the pregnant sow ration would have any demonstrable effect on the number or the live weight of pigs farrowed, or on their growth and health to the time of weaning. It was further planned to study the effects of these supplements in the growing and fattening rations subsequently fed to these pigs. The results of the 1940 trials indicated

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that supplementing the sow ration had no measurable effect on pigs born nor on their progress to weaning. The addition of defatted germ to the market pig rations, however, resulted in an increase in rate of gains and in feed consumption even though the basal rations were already fortified with yeast. The oil fraction gave no measurable effects with the market pigs.

Before going further in ascertaining the factors responsible for these results, it seemed desirable to repeat the 1940 trial to substantiate, if possible, the tentative conclusions then drawn. Arrangements were made for such a replication during 1941, and the results are hereinafter recorded.

DESIGN OF THE TRIAL

The plan of this trial was essentially that followed in the previous study (Crampton (3)). Part I was concerned with the pregnant and nursing periods of the sows, while Part II dealt with the market pigs.

PART I

Eight purebred Yorkshire sows, bred to farrow during January, 1941, were divided into four pairs according to expected farrowing dates. Seventy-five days prior to the first of these dates, all sows were penned individually to permit accurate records of feed for the remainder of pregnancy and during their nursing periods. Excepting for the wheat germ supplements, the rations for all sows were of the same composition: 55% No. 2 C.W. feed barley, plus 30% No. 1 wheat screenings, plus 15% of mixed protein-mineral supplement. The latter was made up to contain 44% meat meal, 15% non-oily fish meal, 20% linseed oilmeal, 10% bone char (iodized at 1.5 oz. per 100 lbs.), 5% ground limestone, 5% salt, and 1% ferric oxide. The mixed ration was fed as a slop (1 lb. to 3 lb. water) in quantities which the sows would clean up readily at each feeding. Pregnant sows were fed twice and nursing sows three times a day. In addition, each sow received daily 1 tablespoonful of cod liver oil (1,800 I.U. "A" and 400 I.U. "D" per gram) and one tablespoonful of a solution of 1 oz. KI in approximately a gallon of water (100 mg. KI per sow daily).

The wheat germ supplements are shown in Table 1.

TABLE 1.—WHEAT GERM SUPPLEMENTS TO SOW RATIONS

Group	Sow No.	Wheat germ supplement
I	142 132	None
II	134 146* 151	Extracted germ (Viobin) as 3% of meal ration.
III	127 147	Extracted germ 3% of meal ration plus ¼ oz. "Rex" wheat germ oil per sow per day.
IV	135 150	One-half oz. "Rex" wheat germ oil per sow per day.

* Sow proved not to be in pig and was replaced by Sow No. 151.

TABLE 2.—BIRTH WEIGHT OF ALL PIGS BORN (LB.)

		Check				Viobin				Viobin + Oil				Oil			
		1940		1941		1940		1941		1940		1941		1940		1941	
		127	147	142	132	150	124	134	151	134	149	127	147	130	143	135	150
		2.3	1.8*	3.2	2.5	2.7	2.6	2.4	2.6	2.2	2.6	3.7	3.2	1.8*	3.0	2.5	2.4
		2.2	2.8	2.9	2.9	2.1	1.9	2.8	2.0	2.3	2.8	3.2	2.2*	2.8	2.6	3.2	2.5
		2.1	2.6	2.9*	3.0	2.5*	3.4	2.6	2.5	1.8*	2.6*	3.6	2.4	2.8	3.0	2.8	3.0
		2.1*	2.3	2.3	3.0	2.4	3.2	2.2*	2.2*	3.2	3.0	3.4	2.3	3.1	2.9	3.2	2.4
		2.8	1.8	2.3*	2.7	2.2	2.2	3.3	2.0	2.2	2.3	3.2	2.3*	2.9	2.7		2.0*
		2.9	2.6	2.6*	2.9	2.2	2.8	2.9	2.6	2.6	2.3	3.5	2.0*	3.2	3.1		3.1
		3.0	2.2*	3.1	2.5	2.6	2.3	3.4	1.6*	2.5	2.5	2.8	1.4*	2.3*	2.9		3.1*
		2.9*	1.3*	2.9	2.9	2.0*	2.8*	2.7	2.0*	2.8	2.0	3.0		2.9	2.4		2.9
		2.5	1.5*	2.4*	2.4	2.9	2.7	2.2*	2.2	2.0*				3.7	2.4		2.6
			1.4*	2.2*	1.6*	2.4*	2.9*	1.3*	1.7*	2.0				2.8	2.5		2.8
				2.8	1.7*	2.9*	1.9*	1.3*	1.0*	2.8				3.0	2.7		2.7
				3.1	1.6*	2.7	1.7*	1.8*		3.3					1.5*		2.7
				3.0	3.3		1.0*			3.3							2.5
				2.0*	3.3												
					2.4												
					1.6*												
					2.6*												
All pigs born	Litter average	2.5	2.1	2.7	2.5	2.5	2.4	2.4	2.0	2.5	2.5	3.3	2.2	2.9	2.6	2.9	2.7
	Year average	2.3		2.6		2.4		2.2		2.5		2.8		2.7		2.7	
	Group average	2.5				2.3				2.6				2.7			
Pigs weaned	Litter average	2.5	2.4	2.9	2.8	2.5	2.7	2.9	2.3	2.6	2.5	3.3	2.6	3.0	2.7	2.9	2.7
	Year average	2.49		2.85		2.6		2.6		2.6		3.1		2.9		2.8	
	Group average	2.7				2.6				2.8				2.8			

*Pigs dying before weaning time.

After farrowing, the pigs remained with their mothers for 56 days. Male pigs were castrated at 4 weeks of age.

The farrowing data for Part II, including both the 1940 and the 1941 results, are given in Tables 2 and 3.

From Table 3, there is no evidence in either year of any increase in the number of pigs farrowed which can be credited to the wheat germ fractions used. Differences in birth weight seem to be more related to the number farrowed than to sow ration. The percentage of pigs farrowed that were weaned, however, appears appreciably higher in the lots fed wheat germ oil. The defatted germ did not have any significant effect in this respect. From Table 2, it is evident that in general it was the small pigs at birth which failed to survive weaning time. Furthermore, the poorer weaning records were from groups averaging the larger litters.

TABLE 3.—SUMMARY OF FARROWING AND WEANING DATA

Treatment Group	Year	Sow no.	Pigs born	Birth weight All pigs	Pigs weaned	Birth weight of pigs weaned	Weaning weight	Gain during nursing 56 days
				lb.		lb.	lb	lb.
Group 2 Check	1940	127	9	2.52	7 63%	2.5	26.8	24.3
		147	10	2.09	5			
	1941	142	14	2.7	8 65%	2.8	27.1	24.3
		132	17	2.5	12			
	Group 1 Av.	4	12.5	2.5	8–64%	2.7	27.0	24.3
Group 2 Defatted Germ (Viobin)	1940	150	12	2.5	8 60%	2.6	29.4	26.8
		124	13	2.4	7			
	1941	134	12	2.4	7 57%	2.6	28.3	25.7
		151	11	2.0	6			
	Group 2 Av.	4	12	2.3	7–58%	2.6	28.9	26.3
Group 3 Defatted Germ plus Wheat Germ Oil	1940	134	13	2.6	11 86%	2.6	28.2	25.6
		149	8	2.5	7			
	1941	127	8	3.3	8 73%	3.1	31.8	28.7
		147	7	2.2	3			
	Group 3 Av.	4	9	2.6	7–78%	2.8	29.6	26.8
Group 4 Rex Wheat Germ Oil	1940	130	11	2.8	9 87%	2.9	29.8	26.9
		143	12	2.6	11			
	1941	135	4	2.9	4 88%	2.8	27.5	24.7
		150	13	2.7	11			
	Group 4 Av.	4	10	2.7	9–90%	2.8	28.8	26.0

Hence to argue that the wheat germ oil caused the greater survival leads to the conclusion that it also caused smaller litters. This seems an unwarranted conclusion in the light of what is known of the physiology of reproduction.

The weaning weights were subjected to a critical examination since the figures might lead one to postulate a significant effect of the feeding to the sow of the defatted germ on the growth of the pigs while nursing. It has frequently been found that weaning weight of pigs at a given age is related to the birth weight. Accordingly, the regression of weaning weight on birth weight, calculated from the variances between pigs of sows on the same feed treatments within the same year, was determined (b = .6891) and the weaning weights adjusted accordingly to the mean birth weight of the whole trial. The values are shown in Table 4.

TABLE 4.—WEANING WEIGHTS OF PIGS

Sow group	Weaning weights of pigs—Av. 1940 and 1941 tests	
	As observed	Adjusted to mean birth weight
	lb.	lb.
Lot I. Check	26.6	26.6
Lot II. Viobin	28.9	29.0
Lot III. Viobin + Oil	29.6	29.6
Lot IV. Oil	28.8	28.9

Evidently difference in birth weight was not an important factor in causing the observed difference in weaning weights. The most difficult feature of the weaning weights to explain is that both the wheat germ oil and the defatted germ gave practically the same apparent increase in pig growth. Since these fractions contain entirely different nutrients one is at a loss to understand why this should be unless each fraction plays an independent rôle. But if so, why does not the combination give a greater effect than observed? This cannot be answered from data of this experiment.

Statistical analysis indicates that the odds are 10 to 1 against the increase in gain in Lots II, III, IV being accidental; or one could conclude that the increase was due to the wheat germ, on the basis of a probability of being wrong in one case in ten. Biologists generally demand odds of not less than 19 to 1 before considering that observed differences are really traceable to imposed treatments.

It would therefore appear questionable whether one would be justified without further evidence in concluding that either of the wheat germ fractions fed to the sows as supplementary to an already highly satisfactory diet had shown any true effect.

PART II

Wheat Germ Fractions for Market Pigs

Experimental Procedure

In order to obtain data as to the effects of wheat germ to market pig rations, 64 of the pigs from the eight litters involved in Part I (1941 test) were allotted at weaning to four feeding groups, using a restricted randomization plan permitting a uniform distribution of pigs from each sow group, but also to include equal numbers of each sex in each group.

This design permitted a scheme of statistical analysis of the 1941 data as in Table 5.

Table 5.—Scheme of partition of variance

Variation due to	Degrees of freedom	
All causes		63
Between 32 Sub groups		31
Between 4 Sow groups	3	
Between 4 Feed groups	3	
Between 2 Sexes	1	
Interaction	24	
Remainder		32

Rations and Feeding Practice

The rations other than for the wheat germ supplements were identical for all pigs. They consisted of No. 2 C.W. barley plus a mixed protein mineral supplement. The latter was composed of:

20 parts meat meal (50% protein)
15 parts fish meal (50% protein, 14% fat)
35 parts linseed meal (34% protein)
10 parts dried brewers yeast
10 parts bone char (iodized — 1.7 oz. per 100 lbs.)
5 parts gr. limestone
5 parts salt

From the start of the test until the pigs weighed about 100 lbs., the feeding mixture consisted of 85% barley plus 15% supplement. Thereafter to market weight (200 lbs.) the proportions were 90% and 10% of basal feed and supplement respectively. The above meal mixture was supplemented with wheat germ fractions as given in Table 6.

All pigs were confined to individual pens during the trial. At feeding time the dry meal allowance was placed in each trough and about three times its weight of water poured over it. No other food or water was fed, excepting that 15 cc. cod liver oil was given each pig daily until he reached the 100 lb. mark. Up to 100 lbs., pigs were fed thrice, and thereafter twice, daily in amounts limited only by appetite.

TABLE 6.—RATION USED FOR MARKET PIGS

Lot	No. pigs	Ration supplement
I	16	None
II	16	Defatted wheat germ (Viobin), 3% of meal mixture
III	16	Defatted wheat germ, 3% of meal; plus wheat germ oil (Rex), 0.5% of meal
IV	16	Wheat germ oil, 0.5% of meal

RESULTS

In Table 7 is given a summary of the essential data from Part II of the trial for the pigs to a weight of 110 lbs.

Statistical analysis shows that the check group pigs were probably less efficient in the use of their feed than those receiving wheat germ supplements.

TABLE 7.—WEIGHTS AND GAINS OF PIGS AND THEIR FEED INTAKES TO 100 LBS.

Lot	Group	Initial weight	Average daily gain to 100 lbs.	Average daily feed	Gain adjusted for differences in feed intakes*
		(lb.)	(lb.)	(lb.)	(lb.)
Lot I	Check	35.7	1.33	4.37	1.31
Lot II	Viobin	34.7	1.34	4.28	1.34
Lot III	Viobin + wheat germ oil	34.1	1.35	4.25	1.36
Lot IV	Wheat germ oil	36.1	1.35	4.31	1.35

* Necessary difference = 0.04 lbs.

There were no marked differences in the appearances of the pigs up to this time, nor any other reactions to the rations which could be spotted by one not knowing the group to which a pig belonged. There was, however, a striking difference between the sexes, as seen in Table 8.

TABLE 8.—GAINS OF PIGS ACCORDING TO SEX

Group	Intial weight	Average daily gain	Average daily feed	Gains adjusted to average feed intake*
	(lb.)	(lb.)	(lb.)	(lb.)
Males	35.4	1.43	4.43	1.39
Females	34.9	1.26	4.18	1.29

* Necessary difference = 0.03 lbs.

When the whole feeding period to a market weight of 200 lbs. is considered, the picture changes in that the check lot pigs had made up their earlier handicap. (See Table 9). In fact, there were no significant differences in gains between any of the four ration groups. It will be noted that, contrary to the first test, there was no evidence of greater feed intake resulting from the ration supplements, so that the gains adjusted for differences in feed consumption did not alter the position of the lots. Sex differences were even more pronounced, however, than at 110 lbs.

TABLE 9.—WEIGHTS AND GAINS OF PIGS ACCORDING TO GROUPS INDICATED. (WEANING TO MARKET WEIGHT OF 200 LBS.)

Lot	Group	Number	Average daily gain	Average daily feed	Gain adjusted to average feed intakes*
			(lb.)	(lb.)	(lb.)
Lot I	Check	16	1.64	5.96	1.62
Lot II	Viobin	16	1.61	5.72	1.61
Lot III	Viobin + oil	16	1.62	5.55	1.64
Lot IV	Oil	16	1.61	5.75	1.61
Male pigs		32	1.71	5.94	1.70
Female pigs		32	1.68	5.54	1.54

* Necessary difference between groups of 16 = 0.08 lbs.
between groups of 32 = 0.06 lbs.

It should be noted that one pig (No. 1117) in Lot IV died of broncho-pneumonia on October 4. Her data were deleted from the test.

CARCASS DATA

Upon reaching a weight of 200 lbs., the pigs were subjected to the slaughter test used in the Advanced Registry examination of carcass from the Dominion Swine Feeding Stations.[3] The data from the carcasses are summarized in Table 10.

TABLE 10.—SUMMARY OF CARCASS DATA

Lot	Group	Average carcass score	Carcass length	Eye of lean	Lean in rasher 1941 only	Rail grading A	Rail grading B	Rail grading C
		%	inches	sq. in.	%	pigs	pigs	pigs
Lot I	Check	82	30.5	5.50	41.7	8	7	1
Lot II	Viobin	80	30.8	5.68	44.7	9	6	1
Lot III	Viobin + oil	80	30.9	5.63	43.1	5	11	0
Lot IV*	Oil	81	30.7	5.38	40.5	8	7	0
Male pigs		77	30.4	5.17	41.1	10	20	2
Female pigs*		83	31.1	6.28	45.7	20	11	0

* Pig No. 1117 in Lot IV died of penumonia, October 14.

[3] We are indebted to the Marketing Service, Dominion Department of Agriculture, for their co-operation in making these examinations.

Excepting between the sexes, no significant differences were found in the carcass measurements; nor in the carcass scores or rail grades. One might note, however, the tendency for the carcasses of pigs receiving the Viobin supplements (Lots II and III) to be fatter than those on other rations. This effect of the non-fat fraction of wheat germ has been strikingly shown in feeding trials at present in progress at Macdonald College. In these latter tests, carcass score was adversely affected, but in the present case, the quantities of wheat germ supplement were relatively small and have had no marked effect. The sex differences were highly significant, statistically and practically. For example, the 31 female carcasses brought \$10.00 more in cash bonuses for grade A carcasses than did the 32 male carcasses.

RECORDS OF THE TWO YEARS' TESTS

The 1940 and 1941 tests were conducted according to the same design, thus making it possible to combine the results and to analyse the variance for the several items of data as illustrated in the case of average daily feed consumed. (See Table 11).

Table 11.—Analysis of variance of feed consumption—1940 and 1941 tests

Variance due to	Degrees of Freedom	Variance	Standard deviation	F values	
				Observed	Necessary
All causes	127				
Between sow groups	3	0.1518			
Between feed groups	3	0.7336		4.69	2.68
Between sexes	1	1.2474		7.97	3.92
Between years	1	16.4237		104.99	3.92
Calculated values	2				
Remainder	117	0.1564	.3955		

This analysis was applied to the items of data used to evaluate the results of the wheat germ additions, together with an analysis of covariance between initial weight, feed consumption and daily gain. This enabled an adjustment of the observed gains to correct for differences in the weights of the pigs when put on test and for differences in the quantities of feed which they ate during the trial. The "adjusted gains" are directly comparable as an index of the growth promoting effect of the diets under consideration. The average values of important items for the combined trials are given in Table 12.

The data presented in Table 12 give the final picture from these trials of the effects on gains of the pigs of fortification of a well balanced market pig ration with defatted wheat germ, wheat germ oil, or a combination of the two. It is seen that the defatted germ has been associated with some increase both in daily gain and in daily feed intake. When adjusted for amounts of feed eaten and for the slight differences in initial weights, statistically significant (odds of 19 : 1) differences were found between

TABLE 12.—SUMMARY OF DATA—1940 AND 1941 TRIALS

Item	Lot I Check	Lot II Viobin	Lot III Viobin + oil	Lot IV Oil	Necessary difference	Males	Females	Necessary difference
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
Number pigs	32	32	32	32		64	64	
Initial weight	34.4	35.3	32.5	35.0		34.4	34.1	
Daily gain to 200 lb.	1.48	1.55	1.52	1.47		1.54	1.44	
Average daily feed	5.46	5.56	5.23	5.28	0.19	5.47	5.27	0.14
Adjusted daily gain*	1.46	1.50	1.56	1.49	0.04	1.53	1.47	0.03

* Adjusted to average feed intakes and initial weight.

the gains made in the several lots. Additions of the defatted germ fraction resulted in faster gains, but any effect of the wheat germ oil is questionable. In general, the use of the Viobin saved the equivalent of something under a week in getting the pigs to market.

The difference between the sexes in gain and in feed consumption was highly significant statistically. These differences were of about the same order of magnitude as those due to ration supplement, and had the trial not been designed to permit measurement of this effect, or had the sexes not been equally distributed between treatments, interpretation of the test might have been difficult if not erroneous.

Table 13 summarizes the carcass data for the two years' tests.

TABLE 13.—SUMMARY OF IMPORTANT CARCASS DATA*

	Lot I Check	Lot II Viobin	Lot III Viobin + oil	Lot IV Oil
Carcass score (%)	81	80	79	80
Carcass length (in.)	30.5	30.6	30.7	30.5
Eye of lean (sq. in.)	5.4	5.6	5.5	5.5
Percentage lean	44.0	46	44	44
Firmness of fat	Firm +	Firm +	Firm +	Firm +
Rail grade—A	17	19	13	18
—B	13	12	18	12
—C	1	1	1	1

*One carcass missing in Lots I and IV.

It is evident at once that none of the treatments has influenced the general excellence of the carcass produced as measured by carcass score. Indeed there is no evidence of any relation between feed and any carcass measurement. The fewer grade A's in Lot III is not justifiably chargeable to the additions of Viobin and wheat germ oil in view of the failure of either of these substances to affect such a condition and the absence of any measurable effect on carcass excellence in any other respect.

CONCLUSIONS

The results of these tests have been reasonably clear cut. We have observed no effect of additions of wheat germ oil either to pregnant sow rations or to those of market pigs.

It seems evident that the defatted fraction of the wheat germ (Viobin) contains a substance or group of substances which when added to the diets of market pigs employed in these tests resulted in measurable increases in growth rate, due probably to stimulation of somewhat greater feed consumption. No effect on carcass measurements was found, however.

In view of the fact that defatted wheat germ is a rich source of vitamin B_1 (thiamin), though not of G (riboflavin) and of the further evidence from rat trials that the most marked visible effect of thiamin supplementation is increased food intake and consequent improved rate of gain, one is led to the conclusion that the increased gain in these trials is probably traceable to the vitamin B complex of the wheat germ used, and perhaps more particularly to its B_1 content.

ACKNOWLEDGMENT

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REFERENCES

1. Boas-Fixsen, M. A. and M. H. Roscoe. Tables of the vitamin content of human and animal foods. Nut. Abs. and Rev., V. 9, No. 4, pp. 795-861. 1940.
2. Council on Foods, Amer. Med. Assn. Accepted Foods, pp. 296-299. 1939.
3. Crampton, E. W. A study of the nutrition value of wheat germ products for swine. Sci. Agr., 21 : 750-758. 1941.

SOME EFFECTS OF NUTRITION ON THE DEVELOPMENT OF THE CODLING MOTH[1]

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Despite the fact that a great deal of research has been applied to the biology of the codling moth, little has been done with respect to the nature of its diet and the influence of diet upon development. On an apple tree, failure of the newly hatched codling moth larva to find a fruit may result in a certain amount of foliage feeding. Should a fruit be encountered, the larva may complete several instars while feeding entirely on the pulp or it may burrow quickly to the core of the apple and complete its development by feeding largely, if not exclusively, on the seeds. Undoubtedly there are wide differences in the chemical composition of the various types of nutriment available to the larva, and it is reasonable to suspect that these types are not equally suitable for the development of the insect.

REVIEW OF LITERATURE

Uvarov (8) refers to Maillot and Lambert who mentioned that since the chemical composition of mulberry leaves fluctuates according to season and even according to time of day the nutritive value of the diet of the silkworm may vary somewhat from month to month or even from day to day. The relationship between maturity of cotton seeds and the behaviour of the cotton boll worm has been studied by Squire (7), who states that larvae completing their development on ripening seeds are likely to go into the resting stage. He believes that this behaviour results from low moisture content of the seeds.

Isley (3) reports that the degree of maturity of fruit has no evident influence on the length of the prepupal period of the codling moth.

The effect of a leaf diet on codling moth development has been described by Speyer (6) who was successful in rearing moths from larvae fed on apple leaves alone. The moths were unusually small and Speyer did not determine if they were capable of producing fertile eggs. Hall (2) also succeeded in rearing larvae to maturity on apple leaves but they failed to form cocoons. Marshall (4) reared larvae on caged non-bearing apple trees but they did not pupate. On the other hand Gentner (1) was successful in rearing codling moths from larvae that had fed on the fleshy spurs of Bosc and Anjou pears.

EXPERIMENTAL PROCEDURE

During the years 1939, 1940 and 1941 experiments were conducted at Vernon and Kelowna, B.C., to determine the role of apple leaves, seeds and pulp in the development of the codling moth larva. Mature as well as immature tissues were utilized. In 1939 the work was done in

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an open insectary with consequent highly fluctuating temperatures. In 1940 and 1941 the experiments were carried on in a laboratory in which both temperature and humidity were more uniform, the temperature varying from 68° to 88° F. and the humidity from 44% to 50% over a 3-month period.

Approximately 2,000 first generation larvae, derived from over-wintered moths, were used in the experiments. When the food material was changed, the larvae were removed and placed on the fresh material by means of a fine camel's hair brush. In spite of the care used in the transfer a certain degree of mortality resulted.

Stoppered vials were used for larvae fed upon seeds and leaves, in order to conserve moisture. The addition of water to raise the humidity to correspond with the assumed humidity within the fruit resulted in the rapid breakdown of the leaves. Larvae reared on immature pulp had an environment more nearly approximating that in nature. They were enclosed in glass jars with apples from which the cores had been removed and substituted by plugs of paraffin wax. Although these apples showed no tendency to rot, the larvae on them were subsisting on steadily deteriorating tissues, whereas those feeding on leaves and seeds were provided with fresh food daily or every other day.

When mature pulp was fed, the apples were cored and cut in sections and the cut surfaces coated with paraffin wax. Delicious apples that had been in cold storage for 8 months were used, consequently the sections decayed fairly rapidly and had to be renewed at intervals of 3 or 4 days.

EXPERIMENTAL RESULTS

In Table 1 are summarized the data for the 3 years' investigations. Since there was comparatively little variation in the results from year to year, averages are sufficient to show that the several types of diet available to the codling moth larvae are by no means equally suitable for supporting its development.

TABLE 1.—EFFECT OF DIET ON DEVELOPMENT OF CODLING MOTH

Diet	Total larvae	Cocooned larvae	Av. days feeding	Av. days in cocoon	Male moths	Female moths	Larvae in diapause	Fertility of eggs
Immature seeds	518	173	16.6	17.4	67	67	1	Fertile
Immature pulp	496	246	22.6	20.4	69	87	27	Fertile
Mature seeds	140	0	—	—	0	0	0	—
Mature pulp	150	10	29.4	15.7	3	0	0	—
Leaves	500	32	31.9	15.8	8	10	0	Infertile
Normal fruit	60	47	20.3	16.3	10	21	0	Fertile

Development was most rapid on immature seeds, some larvae attaining maturity in the short space of 10 days in June and July. To complete their development the larvae consumed from 3 to 6 times their mature weight in immature seeds.

In the 1940 experiments the larvae had great difficulty in penetrating the hard seed coat of mature apple seeds of the previous year's crop. In June and July all of 80 larvae succumbed within 12 days. In mid-August

1941, mature seeds of the 1940 crop were more effective in sustaining the larvae. Nineteen of 60 larvae lived for periods of 17 to 39 days. No larvae cocooned on a diet of mature seeds.

On a diet of immature pulp, development of larvae that hatched July 2 to 4 was slightly slower than on a diet of immature seeds. This applied both during feeding and in the cocoon. A higher percentage of larvae entered diapause when fed on immature pulp than on any of the other types of diet.

On a diet of mature pulp during the same period, only 10 of 150 larvae formed cocoons. Of these 10 none entered diapause and 7 died without transforming. A characteristic of larvae fed upon mature pulp was the prolongation of the developmental period. All except 7 of 150 larvae lived for 18 days or more, 12 for 50 days or more while 2 lived for the remarkably long periods of 101 and 105 days respectively.

On a leaf diet a greater percentage of larvae transformed into moths in 1941 than in the previous two years. The increase is thought to be due to the fact that in 1941 only immature leaves were used; the experimental feeding that year commenced soon after the buds had opened. All moths derived from larvae fed on leaves were about half the normal size, and none lived over 5 days after emerging. No mating was observed and no eggs were obtained from 7 females and 4 males placed together in 1941 although under similar conditions eggs were readily obtained from normal moths.

Larvae reared on leaves spent less time in the cocoon than those reared on any of the other diets but the feeding period was considerably longer. Speyer has noted the protracted later instars resulting from a leaf diet. This condition has been found in the present investigation to result largely from an extended quiescent period both before and after moulting. The larvae had much difficulty in breaking and casting the cuticle and many died during ecdysis. Inadequate humidity in the jars enclosing leaves may have contributed to this difficulty. On the other hand development was no more rapid, and no larvae cocooned on a diet of leaf petioles into which the larvae were able to burrow and thus secure what might be expected to be a more favourable environment than that of larvae feeding openly on leaf mesophyll.

Leaves picked late in the day and leaves picked in the morning appeared to have about the same nutritional value, since of 12 larvae that cocooned in 1941, 6 developed on leaves collected in the morning and 6 on leaves collected in the evening. There was no instance of diapause on a leaf diet although four larvae in 1940, and one larva in 1941, moulted for a fifth time and then transformed into intermediates having both larval and pupal characteristics. These anomalies retained most of their larval characters but the antennae were 3 to 10 times as long as the larval antennae. The mandibles and spinneret on the other hand were reduced in size as compared to the larval condition. Both of these structures normally become vestigial in the pupa. Except in one doubtful case of a larva reared on mature pulp, abnormal forms resulted only from a diet of leaves but none resulted from an exclusive diet of leaf petioles. All the intermediates died without further development. Some larvae on leaves survived for as long as 65 days without cocooning.

SUMMARY

Experiments were conducted with codling moth larvae to determine the comparative nutritive values of seeds, pulp and leaves of apple. Results indicated that immature tissues have a greater nutritive value than mature tissues. An exclusive diet of immature seeds appeared to accelerate development but seeds were not found to be essential to fertility of the moths. The absence of seeds did not appreciably retard development providing immature apple pulp was available, although a significant number of the larvae deprived of seeds underwent diapause. Mature pulp and mature seeds, both evidently unfavourable for larval growth, tended to increase larval longevity at the expense of development. On a leaf diet several larvae developed into moths which were undersized and short lived. Intermediate forms having both larval and pupal characteristics occurred only on a diet of leaves. None of the larvae that fed on petioles transformed though they lived for periods up to 42 days. No difference in nutritional value was observed between leaves picked in the morning and leaves picked in the evening.

REFERENCES

1. GENTNER, L. G. 1940. Spur burrowing habit of codling moth larva on pear trees. J. Econ. Ent. 33 (5) : 796-799.
2. HALL, J. A. 1934. Observations on the behaviour of newly hatched codling moth larvae. Can. Ent. 66 (5) : 100-102.
3. ISLEY, D. 1939. Timing seasonal occurrence and abundance of the codling moth. Arkansas Agr. Expt. Sta. Bull. 382, pp. 1-26.
4. MARSHALL, G. E. 1940. Some newly discovered habits of the codling moth. J. Econ. Ent. 33 (1) : 200.
5. SKOBLO, I. S. 1939. The effect of the environmental conditions of the pyralid moth *Loxostege sticticalis* on the viability of the deposited eggs [in Russian] Plant Prot. (Moscow) 19 : 153-157. *Cited in* Rev. Appl. Ent. 28 (A) (3) : 130, 1940.
6. SPEYER, W. 1932. Can the codling moth develop on leaves alone? [Transl. title] Arb. Biol. Reichsanst. Land u. Forstw. 20 (2) : 183-191. *Cited in* Exp. Sta. Rec. 69 (6) : 831.
7. SQUIRE, F. A. 1937. A theory of diapause in *Platyedra gossypiella* Saund. Trop. Agr. Trinidad 14 (10) : 299-301. *Cited in* Exp. Sta. Record 80 (4) : 517.
8. UVAROV, B. P. 1928. Insect nutrition and metabolism. Trans. Ent. Soc. London. 96 : 255-343.

CONTRIBUTIONS TO THE STUDY OF RANCIDITY IN CANADIAN CHEDDAR CHEESE

II. THE GROWTH OF BUTYRIC ACID ANAEROBES IN CHEDDAR CHEESE

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In a previous paper (3) it was shown that butyric acid anaerobes were frequently found present in relatively small numbers in rancid cheese. Still smaller numbers of these organisms were also found present in many normal cheese. The limited numbers of these bacteria, in spite of their fairly wide distribution, suggest their inability to grow in normal cheddar cheese. Certain observations made by others tend also to confirm this view. Demeter (4) said: "that by the clever use of good starters even the strongest contaminations by butyric acid organisms can be paralysed." Ernst (5) observed that milk invariably contains butyric acid bacilli but their predominance is inhibited by lactic acid formation. On the other hand Burri (2), Orla Jensen (7), Van Beynum and Pette (9), Boekhort and Van Beynum (1), Ritter (8) and a great many other European bacteriologists have found that these organisms can and do develop in cheese under certain circumstances, and cause various types of spoilage. Although Hood and White (6) were unable to produce typical rancidity in cheese by the addition of *Cl. butyricum*, they were able to produce "very rancid" cheese by inoculations with whey-soaked soil, presumably rich in these organisms.

The object of the experiments outlined in this paper is to find out to what extent butyric acid anaerobes with and without other species of bacteria are able to grow, to form spores, and to germinate spores when inoculated into chedder cheese.

The butyric anaerobe (designated as "Wales" clostridium) used in most of the tests was one isolated from a typical rancid cheese. It had the characteristics of *Cl. butyricum*, as given by Bergey's manual. Other identified species from various sources have also been used.

By making intermittent dilution counts in corn-liver and in grass media a check was kept on the growth and activity of these organisms during the manufacturing and curing of the cheese. In order to differentiate the number of spores from the number of vegetative cells, counts were made before and after pasteurization.

In most instances the fresh milk was inoculated at 5 o'clock in the evening and held at 10° C. until the following day at noon when the cheese-making began. Except that the cheese were small (10 pounds), all the ordinary procedures were carried out. They were cured at 15° C. It might also be remarked that the milk itself was of a very high quality, with a usual bacterial plate count of around 10,000 per ml.

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The following were the variations of inocula used:

1. Wales' clostridia in active vegetative stage
2. Wales' clostridia in spore stage
3. Same as No. 1 using pasteurized milk for the cheese
4. Same as No. 2 using pasteurized milk for the cheese
5. Wales' clostridia + 4 different cultures of *Ps. fluorescens*
6. Wales' clostridia + a soil organism
7. Wales' clostridia + 2 yeast cultures isolated from rancid cheese
8. Wales' clostridia + *E. coli* and *Aer. aerogenes* + *Alc. faecalis*
9. Wales' clostridia + *P. vulgaris* + *Alc. viscosus*
10. Wales' clostridia + *Oidium lactis.*

Before adding the inoculum to the milk, attempts were made to estimate the number of cells present by direct microscopical count; using these counts, the inoculum was added so as to start with approximately 10,000 clostridia per ml. of milk.

The first dilution counts in the enrichment media were made from the freshly inoculated milk, from which counts were made again, immediately before the lactic starter was added to it in the vat. Counts were made from the cheese as soon as they were released from the press and thereafter at constant intervals for a period of at least 2 months.

Both corn-meal and grass enrichment media were used in every instance, which resulted in 148 duplicate dilution counts for these first ten experiments.

The results in every case were almost identical and are illustrated by the counts from No. 1 and No. 2 experiments as shown in Table 1. There is nothing to indicate that these organisms grew either in the milk or in the cheese, or that spores germinated, or that the vegetative cells formed spores. The addition of the aerobic cultures, which have a symbiotic action with butyric anaerobes under other conditions, made little difference to their activity in the cheese up to the end of 4 months.

TABLE 1.—COUNTS, AS SHOWN BY GROWTH IN ENRICHMENT MEDIA, OF CLOSTRIDIA IN TWO LOTS OF INOCULATED MILK AND THE CHEESE MADE FROM THEM

Material	Date	Inoc. with vegetative cells		Inoc. with spores only	
		Total	Spores†	Total	Spores†
Milk	Jan. 10	3*		3	
Milk	Jan. 11	3		3	
Cheese	Jan. 13	4	0	4	3
Cheese	Jan. 14	4		5	
Cheese	Jan. 15	4		5	
Cheese	Jan. 17	3		5	
Cheese	Jan. 20	4	0	4	4
Cheese	Jan. 23	4		3	
Cheese	Jan. 24	4		4	
Cheese	Jan. 27	4	0	5	4
Cheese	Jan. 30	3		4	
Cheese	Feb. 3	5		5	
Cheese	Feb. 7	3		4	
Cheese	Feb. 11	3	0	3	3
Cheese	Feb. 17	4		4	
Cheese	Mar. 27	3		2	

* The figures represent the log of the counts.
† Only four counts were made to determine the presence of spores.

Some of the cheese developed offensive odours and flavours, especially those heavily inoculated with the soil aerobes, but none developed anything closely resembling the typical butyric acid-like rancidity.

Further inoculations with other Clostridia

Thirteen more experimental cheese were made from inoculated milk and their counts of butyric-acid-forming clostridia were obtained as previously described. The objects of these tests were as follows:

1. To determine the effect of heavy and light salting.
2. To determine whether other strains and species of butyric acid organisms will multiply in normal cheese.
3. To determine whether the natural flora of butyric acid organisms in sour silage and in sour soil from near a whey tank will develop in cheese.

The following were the inocula used:

11. Wales' clostridia (cheese salted $2\frac{1}{2}$ lbs. per 1,000)
12. Wales' clostridia (cheese salted 2 lbs. per 1,000)
13. *Cl. butyricum* (cheese heavily salted)
14. *Cl. butyricum* (cheese lightly salted)
15. Washings from good silage
16. Washings from spoiled sour silage
17. Milk inoculated with silage and incubated 24 hours at 7° C.
18. Washings from sour soil near a whey tank.
19. Washings from ordinary soil.
20. *Cl. pasteurianum* } + *Serratia marcescens*
21. *Cl. acetobutylicum* } + *Serratia marcescens*
22. *Cl. butyrium* No. 1 } + *Serratia marcescens*
23. *Cl. butyricum* No. 2 } + *Serratia marcescens*

In brief, the results were the same as in the first set of experiments. There was no evidence of growth or activity of the butyric acid anaerobes in the cheese, and there was no development of rancid flavour.

DISCUSSION

Burri (2), in speaking of the development of butyric acid anaerobes in sweet ensilage has this to say: "the measure of their development is dependent upon very distinct conditions *that have not yet been discovered.*" Something similar appears to be the case in regard to their growth in cheddar cheese. This may be a nutritional growth factor; it may be a change in the physical-chemical nature of the cheese; or it may be some indirect factor, such as partial inhibition of lactic acid organisms by bacteriophage or excess amounts of lipase activity.

Quite apart from the question of the growth of the butyric anaerobes, there is nothing in these or the observations of the preceding paper to show that they are the causal agent of ordinary rancid cheese, and much to suggest otherwise.

SUMMARY

In 23 experimental cheese made with milk inoculated with butyric acid anaerobes, or material containing them, in no instance was there an increase in the number of cells, sporulation, or germination of spores during a period of two months.

The addition of various aerobes, and the reduction of the percentage of salt made no difference in these results.

In no instance was a rancid flavour produced in cheese by inoculations with butyric acid anaerobes.

REFERENCES

1. Boekhout, F. W. J. and J. Van Beynum. Over het "laat optredend los" bij Goudsche Kaas. Vereenig. Exploit. Proefzuivelboerderij. Hoorn, Verslag 1928/1929: 1-8. 1929. (Abst. in Biol. Absts. 5, No. 1 entery 1740).
2. Burri, R. The relation of ensilage to cheesemaking. Proceedings of the world's dairy congress. Washington, 1924.
3. Castell, C. H. Contributions to the study of rancidity in Cheddar cheese. I. Butyric acid clostridia in rancid cheese. Sci. Agr. 22 : 131-134. 1942.
4. Demeter, K. J. Control of anaerobic sporeformers in Emmental cheese making. J. Bact. 25, 64-65. 1933.
5. Ernst, W., J. R. Mohler and A. Eichhorn. Milk Hygiene. Alexander Eger, Chicago. 1914.
6. Hood, E. G. and A. H. White. Rancid flavour in Cheddar cheese. Bull. 146 New Series. Dept. Agr., Ottawa. 1931.
7. Orla-Jensen. Dairy Bacteriology. J. and A. Churchill, London. 1921.
8. Ritter, P. Beiträge zur Frage der nachträglichen Blähung von Alptalkäsen. Schweiz. Milchztg. 64, 179-181. 1938. (Abst. in Dairy Science Abstracts Vol. 1 No. 1 p. 75. 1939.)
9. Van Beynum, J. and J. Pette. Fermentations in silage with reference to cheese-making. Rept. for 1934 of the Expt. farm, Hoorn Holland. (Abst. in J. Dairy Sci. 2, A-121. 1937).

EGG YOLK COLOUR AS INFLUENCED BY SALMON OILS IN THE DIET

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As a result of a scarcity of feeding oils, and the consequent development of the salmon oil industry in Canada, blends of oils containing salmon oil have come into use. Titus *et al.* (3) showed that the carotenoid pigments containing one, two or three hydroxyl groups are readily transferred from the feed to the yolks of the eggs. Since salmon oils, salmon egg oils and blends of such oils are high in certain carotenoid pigments, at least two of which have similar properties to astacin (Bailey (1)) it was considered that the presence of these oils in the diet of laying hens might have some effect on egg yolk colour. An experiment was conducted to yield information on this hypothesis, since no reference to this point could be found in the literature.

METHODS

The birds used in the test were New Hampshires, the majority being pullets and the remainder yearling hens. The birds were confined in individual laying batteries so that the eggs from each bird could be identified. Each group of birds consisted of a randomized sample of 24 and there were 6 groups in all.

The colour of the egg yolk was determined by the use of the "Color Rotor," a device developed by the Washington Agricultural Experiment Station (Heiman and Carver (2)) as a yolk colour index.

The colour of the normal yolks was established by taking readings while the birds were being fed on a balanced battery mash which contained no salmon oil (the ration of Group 1, Table 1). In so far as possible three eggs from each bird, laid within a period of not more than 10 days, were used to establish the yolk colour for each bird's eggs.

Having established the yolk colour for all groups on this ration, the birds were placed on their respective experimental rations. At the end of two weeks on these rations a second set of readings was taken. A third set of readings was taken at the end of one month on the experimental rations. In these second and third readings three eggs from each hen collected within a 10-day period were again used to establish the colour for each individual.

The basal ration is presented in Table 1 (a) and the experimental rations in Table 1 (b).

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TABLE 1 (a).—COMPOSITION OF BASAL RATION

Ingredient	Pounds	Ingredient	Pounds	Ingredient	Pounds
Ground wheat	17.5	Wheat germ	2.25	Ground oyster shell	5.00
Ground barley	12.5	Oil cake meal	1.25	Feeding bone meal	0.25
Ground oats	7.25	Soya bean oil meal	1.50	Ground limestone	0.25
Oat middlings	5.00	Meat meal	5.00	Iodized manganized salt*	0.25
Wheat middlings	5.00	Fish meal	1.50	Cereal grass	2.00
Wheat bran	5.00	Powdered buttermilk	1.50		
				Total	78.25

TABLE 1 (b).—COMPOSITION OF EXPERIMENTAL RATIONS

Ingredients	Groups					
	1	2	3	4	5	6
Basal	78.25	78.25	78.25	78.25	78.25	78.25
Ground yellow corn	21.50	20.75	20.75	20.75	20.75	21.50
Cod liver oil (400 D)	0.25	—	—	—	—	—
Salmon oil 1 (100 D)	—	1.0	—	—	—	—
Salmon oil 2 (100 D)	—	—	1.0	—	—	—
Salmon egg oil (100 D)	—	—	—	1.0	—	—
Commercial feeding oil 1 (100 D)	—	—	—	—	1.0	—
Commercial feeding oil 2 (400 D)	—	—	—	—	—	0.25
Total	100.	100.	100.	100.	100.	100.

* The salt contained 0.02% KI and 0.2% $MnSO_4.4H_2O$.
Oyster shell and insoluble grit were supplied ad lib.

Salmon oils 1 and 2 differed in that they were different blends of oil from several species of salmon and represented different proportions of oil from heads and oil from livers. Consequently, these two offal oils differed somewhat in pigment content. The salmon egg oil used was produced from mixed salmon eggs while commercial feeding oil 1 was a blend of salmon oil with other oils of non-salmon variety. Commercial feeding oil 1 was typical of commercial blended feeding oils in which a moderate proportion of the blend was salmon oil. All the above mentioned oils had a vitamin D potency of approximately 100 A.O.A.C. units per gram. The commercial feeding oil 2 used in the ration of Group 6 was another commercial blended fish oil in which some salmon oil was used but which had a vitamin D potency of approximately 400 A.O.A.C. units per gram.[4]

RESULTS

The results of these experiments are shown in Table 2. The three readings for each hen during each of the three periods have been averaged and the means of these averages computed. This gives a reading representative of the group for any one period, and is therefore termed the "colour index" of the period.

TABLE 2.—COLOUR INDICES

Group No.	Colour index of period 1*	Colour index of period 2†	Colour index of period 3‡
1	15.25	13.15	13.25
2	15.00	13.00	13.40
3	14.80	13.60	13.20
4	14.95	14.15	14.10
5	14.85	12.85	13.50
6	14.65	12.65	13.90

* Period 1 represents readings on negative control ration.
† Period 2 represents readings after 2 weeks on experimental ration.
‡ Period 3 represents readings after 1 month on experimental ration.
[4] We are indebted to the Fisheries Research Board of Canada, the British Columbia Packers, and the National Oil Products Co. of New Jersey for the fine co-operation in supplying oils for this experiment.

DISCUSSION

Although individual hen readings have not been presented here, it was noted, when comparing the indices of the different periods in the same group or those of the same period in different groups (Table 2) with the individual readings, that the variation between these indices was no greater than the variation between the readings of many of the individual hens during any one period and not as great as the differences between the average readings of different hens in the same group during any one period. In addition, as can be seen in Table 2, there is no significant difference between the negative control group (1) and the groups receiving salmon oils.

It is interesting to note that all the colour indices of period 1 are higher than the indices of periods 2 and 3. Since this decrease in intensity of colour occurred in all groups inclusive of the negative control, it seems possible that a seasonal change in yolk colour may have been involved here.

CONCLUSIONS

1. The salmon oils, salmon egg oil, commercial feeding oil 1 and commercial feeding oil 2 used in this experiment when added to the diets of laying hens in amounts sufficient to supply the vitamin D requirements, had no adverse effect on yolk colour.
2. Some probability of seasonal variation in yolk colour is indicated.

ACKNOWLEDGMENTS

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REFERENCES

1. BAILEY, B. E. The pigments of salmon. J. Biol. B.D. Can. 3 (5). 1937.
2. HEIMAN, V. and J. S. CARVER. The yolk color index. U.S. Egg & Poultry Magazine, 41 : 40-41. 1935.
3. TITUS, H. W., J. C. FRITZ and W. R. Kauffman. Some observation on egg yolk color. Poultry Science 17 : 40-45. 1938.

NEW MINIATURE THRESHER

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One of the greatest needs of the plant breeder and seed producer is a simple, easily cleaned threshing mill. For many years plant breeders throughout the world have been endeavouring to develop and perfect mechanical means for threshing plots of various sizes, with the result that very substantial progress has been made in this field.

The Cereal Division, Central Experimental Farm, has tried out a number of the most promising models, and now has machines for head rows

Figure 1. Fan type plot thresher with feed pan and cyclone collector. Piping is used for the frame of the threshing device and motor mounting. A switch box is conveniently located on the motor. Seed and straw is collected in a pail placed below the collector.

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and for larger rod row plots. Because of the War and the increasing scarcity of experienced help, it was necessary to find some simple, efficient means of threshing the thousands of single row plots which are too large for the head row machine and too small for the larger machines.

The problem of developing a suitable machine to handle this type of material has engaged the attention of the Agricultural Engineering staff of the Field Husbandry Division, and of certain officials of the Cereal Division during the past year or two. As an outcome of their deliberations, a machine was built during the past season which is now in daily use.

This machine has the desired features of simplicity and ease of cleaning, and speeds up the work enormously. While the present machine is not entirely perfect, it undoubtedly is a decided advance and one which may prove to be the basis upon which to make further improvements.

The new miniature machine is used to thresh barley, flax, oats and wheat when grown in small plots of from 4 to 6 feet in length. Most of this material is of a hybrid nature, and must be handled without loss or mixing. The machine handles work of this nature in a very satisfactory manner.

The operation of the mill is quite simple; the heads of grain, with several inches of straw attached, are emptied from small bags into a tray which acts as a chute down which the heads are pushed into the mouth of the mill, where they are beaten against a rubber covered shelling plate by the rubber faced angle irons of the rotating disc. The threshed material—

FIGURE 2. Side view of threshing unit with cover plate removed. The cover plate has been reversed to show the rubber faced feed plate and secondary threshing plate which are bolted to the inside of fan cover plate.

FIGURE 3. Corner view of fan type plot thresher. The feed pan can be turned upside down for cleaning.

straw, chaff and grain—is blown into a sheet-metal cyclone, and from there drops into a pan placed below the funnel. The straw is then shaken out by hand, and the grain run over an inclined chute against which a current of air from an electric fan is directed. This effectively removes the chaff and light grain, leaving the clean sample which is caught in a suitable receptacle.

Where samples are difficult to thresh, it has been found useful to pass the material through twice, or even three times. This incidentally furnishes an index or record of the "ease of threshing" of the variety.

The mechanical details of this miniature threshing machine are as follows. The fan is of the furnace type and is made by the Canadian Blower & Forge Company. This acts as a thresher of the self-cleaning type. There is no separator unit on this device. The fan speed is controlled by a four-step pulley, having a range of 1400 to 2500 revolutions per minute. A speed of 1400 to 1800 per minute is found to be the most satisfactory

speed for threshing grain. The rotator of the fan is replaced by a disc approximately 10 inches in diameter and about ½ inch in thickness. To this are attached six, 4-inch rubber-faced angle irons which were procured from the cylinder of a small combine.

The mouth of the machine on the blower side plate is about 4 inches square, and has a rubber-faced angle iron shelling plate on the inside. Attached to the fan cover plate is a second rubber-faced shelling plate or concave which is removable. Plates are brazed to the outside of the fan plate to accommodate the seed pan. The blower is attached to a 15-inch by 26-inch sheet metal cyclone by a short length of 3-inch sheet metal piping. The whole blower and cyclone is mounted on a 1-inch iron pipe frame 34 inches high, 40 inches long and 21 inches wide, and the blower itself is driven by a ½ H.P. dust proof motor. A hinge mounting is used on the motor to obtain belt tension and to facilitate belt changes in fan speed adjustments.

It is realized that this new miniature threshing machine is neither perfect in design nor complete in all details, but it is intended, when time permits, to develop equipment which, when attached, will provide a finished grain sample and be nearly continuous in operation.

MANIFESTATION EXTRÊME DE LA GERÇURE DES PÉTIOLES DU CÉLERI[1]

MALADIE PAR CARENCE DE BORE

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(Reçu pour publication 15 mai, 1942)

INTRODUCTION

Durant les étés de 1937 et 1938 les expériences poursuivies à Charny, près de Québec, par la Station Expérimentale Fédérale de Cap-Rouge, sur le céleri cultivé en terre noire, ont été annihilées par la gerçure des pétioles et la présence d'une atrophie ou pourriture sèche du cœur accompagnée de nanisme.

Les autorités de cette station expérimentale informèrent le premier auteur, lors d'une visite pour enquête générale sur les maladies des plantes à Cap-Rouge et à Charny, qu'elles se verraient forcées d'abandonner ces essais si les résultats de 1939 n'étaient pas meilleurs que ceux des années précédentes.

Une maladie apparemment similaire ayant été signalée par Gram (2) sur le céleri-rave, *Apium graveolens rapaceum*, les auteurs décidèrent de tenter des essais avec le bore dans le but de corriger cette atrophie du cœur, trouble apparemment physiologique, puisque aucun organisme n'avait pu être isolé des plants malades. Ils étaient d'ailleurs assurés d'éliminer par ces traitements la gerçure des pétioles (3).

Une enquête très sommaire faite au mois d'août 1939 dans la région maraîchère s'étendant de Québec à Deschambault nous a permis de constater que ces deux maladies, et notamment la gerçure des pétioles, sont assez communes et méritent une attention particulière.

DESCRIPTION DE LA MALADIE

Durant les premières semaines qui suivent la transplantation, la croissance du céleri est normale mais elle diminue peu de temps après et cesse totalement vers la fin de juillet. Sur les pétioles externes apparaissent, le long des arêtes des rainures, des stries d'un brun rouille. Plus tard l'épiderme et les faisceaux de collenchyme se fendillent transversalement, se soulèvent aux extrémités et s'enroulent (Figure 1), formant ainsi des gerçures qui, avec le temps, deviennent de plus en plus nombreuses (Figure 3). Les pétioles sont rigides et cassants de sorte qu'il est difficile de les écarter sans les briser. Les pétioles internes, partie intégrante du cœur, ont une croissance très anormale. Ils se courbent et s'entrelacent (Figures 3 et 4), puis brunissent et se dessèchent graduellement. Ce brunissement et ce dessèchement prennent naissance à l'extré-

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FIGURE 1. Pétioles de céleri affectés de gerçure. A noter: les arêtes des rainures brunies et l'épiderme fendillé et soulevé.

FIGURE 2. Plant affecté d'atrophie du cœur en regard d'un plant normal.

mité des jeunes folioles et envahissent graduellement les pétioles jusqu'à leur base, si bien que ces derniers finissent par disparaître complètement comme s'ils avaient été pulvérisés. (Figures 3 et 4). A la fin de la saison, il ne reste plus du plant de céleri qu'une couronne de pétioles externes, dont la surface adaxiale est brune et de consistance liégeuse, entourant une cavité. Le fond de cette cavité, qui est brun, n'est autre que la tige proprement dite (Figures 3 et 4).

Cette maladie se diagnostique facilement: (1) à la taille très réduite des plants dont la hauteur varie généralement de 4 à 7 pouces (Figure 2); (2) à l'atrophie et à la pourriture sèche des pétioles du cœur dont toutes les gradations peuvent s'observer dans une même plantation; (3) à l'apparence liégeuse de la surface adaxiale des pétioles externes (Figure 4); (4) à la présence de gerçures et au brunissement des arêtes des rainures sur leur surface abaxiale (Figures 1 et 3).

Il est important de distinguer cette atrophie du cœur d'une autre forme de pourriture appelée "cœur noir" (Blackheart).

Le cœur noir, dont la cause certaine reste à déterminer, est essentiellement une forme de pourriture sèche d'après Foster et Weber (1). Cette pourriture devient une pourriture molle à la suite de l'envahissement des tissus affectés par des saprophytes; elle apparaît tout aussi bien, même plus fréquemment, sur des plants adultes de, dimension, de croissance et d'apparence normales, que sur des jeunes plants (4). Au con-

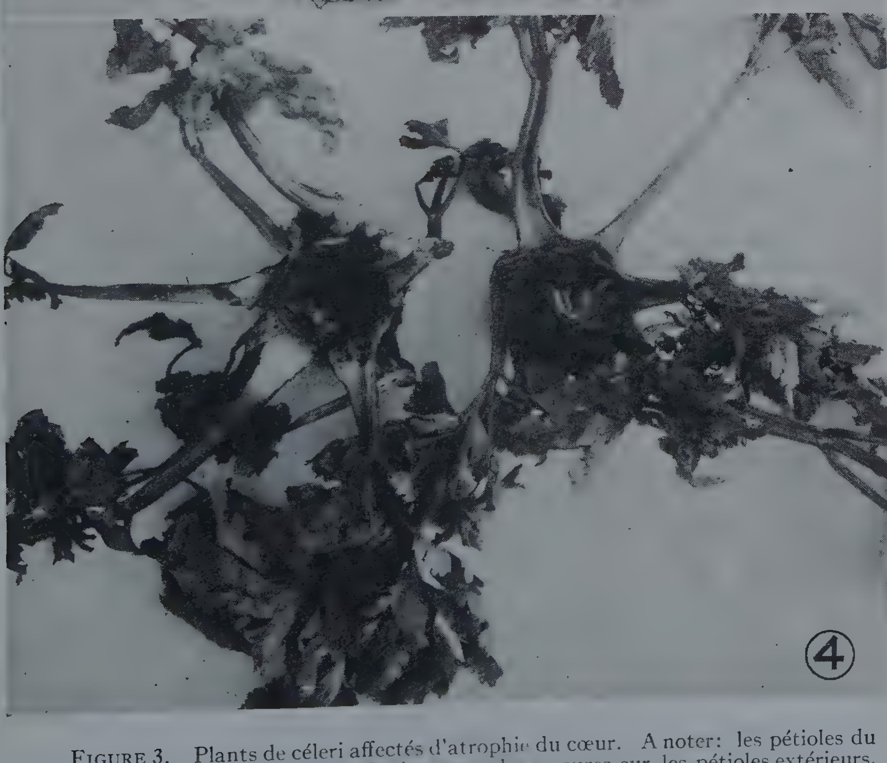

FIGURE 3. Plants de céleri affectés d'atrophie du cœur. A noter: les pétioles du cœur entrelacés et courbés, les stries brunes et les gerçures sur les pétioles extérieurs.

FIGURE 4. Mêmes plants que ceux de la Figure 3. A noter: la croissance anormale des pétioles du cœur sur le plant de gauche, la pourriture complète du cœur du plant de droite et l'apparence liégeuse de la surface adaxiale des pétioles externes.

traire, l'atrophie du cœur causée par une carence de bore ne se rencontre que sur des plants nains et est invariablement accompagnée de gerçure des pétioles.

En autant que les auteurs sachent, jusqu'ici cette phase de la gerçure du céleri n'a pas été décrite ni signalée. Gram (2) en 1936, note qu'au Danemark il existe une pourriture sèche du cœur du céleri-rave, *Apium graveolens rapaceum*, apparemment consécutive à de généreux amendements calcaires. Il rapporte qu'une application de 15 à 30 kgs de borax à l'hectare suffit pour enrayer cette maladie. Bien que Gram ne donne aucune description de cette maladie, une figure en regard du texte permet de croire qu'il s'agit d'une maladie similaire.

TRAVAIL EXPÉRIMENTAL

Le travail expérimental fut fait à même les parcelles de la Station Expérimentale Fédérale de Cap-Rouge. Les rangs de protection furent utilisés pour faire les traitements, tandis que les rangs du centre furent considérés comme témoins. De cette façon, le plan des expériences de la station expérimentale ne fut bouleversé d'aucune manière.

Bien que les rangs de protection de toutes les parcelles aient reçu du borax, il n'est ni opportun ni utile de présenter le plan complet des expériences poursuivies à Charny par la Station Expérimentale Fédérale de Cap-Rouge, expériences relatives à l'influence de certains fertilisants sur la croissance et le rendement du céleri en terre humifère. Les auteurs se borneront donc, dans cet article, à l'aspect strictement phytopathologique et compareront les effets du bore sur trois seulement des traitements compris dans l'expérience.

Les expériences de la Station Expérimentale Fédérale de Cap-Rouge étaient en cours depuis 1937, ce qui permit de recueillir quelques indications concernant l'effet des amendements calcaires sur l'immobilisation du bore dans le sol. Bien que les expériences qui font le sujet de cet article n'aient été faites qu'une seule année, à savoir en 1939, les résultats sont tellement marqués qu'ils justifient leur présentation.

Les trois traitements comparés sont les suivants: (1) parcelles recevant un engrais complet de formule 2-8-16 à raison de 2,000 livres à l'acre et 200 livres de muriate de potasse en couverture; (2) parcelles recevant le même traitement que (1) plus 1,000 livres de chaux hydratée à l'acre; (3) parcelles recevant le même traitement que (1) plus 2,000 livres de chaux hydratée à l'acre. Chacun de ces traitements était en triplicata, ce qui fait en tout neuf parcelles.

Des quantités de borax furent étendues à la main, au pied des plants, sur les rangs de protection, à raison de 5, 15 et 25 livres à l'acre, tandis que les rangs du centre ne reçurent pas de borax et constituèrent les parcelles témoins. Chaque traitement plus haut mentionné reçut les trois quantités de borax.

Les parcelles furent visitées à deux reprises durant la saison de végétation et les notes furent prises lors de la récolte.

TABLEAU 1.—TABLEAU INDIQUANT LES RENDEMENTS MOYENS, LA HAUTEUR MOYENNE, LES POURCENTAGES DE GERÇURE DES PÉTIOLES ET D'ATROPHIE DU CŒUR OBTENUS AVEC LES DIVERS TRAITEMENTS. MOYENNE DE 100 PLANTS

Engrais utilisé, en livres, à l'acre		Bore	Rendement en livres	Hauteur moyenne des plants en pouces	Indice de gerçure	Indice de pourriture sèche du cœur
2,000 lv. 2-8-16 et 200 lv. KCl en couverture	Chaux, 0	0	91.5	9	85	16
		5	103.0	16	26	0
		15	133.2	23	1	0
		25	112.5	20	0	0
	Chaux, 1,000	0	68.8	8	90	45
		5	99.5	20	5	0
		15	114.9	24	0	0
		25	98.2	18	0	0
	Chaux, 2,000	0	61.5	9	89	61
		5	102.6	18	10	35
		15	117.5	20	0	0
		25	125.1	18	0	0
Moyenne		0	77.3	9	88	41
		5	101.7	18	14	12
		15	121.6	22	0	0
		25	112.9	19	0	0

RÉSULTATS

Les résultats sont condensés dans les Tableau 1 et Figure 5. Ces tableaux indiquent clairement que:

1°. L'addition de borax en quantité optima améliore sensiblement les rendements dans les parcelles qui n'ont pas reçu de chaux et les doublent ou presque dans les parcelles qui en ont reçue;

2°. L'effet d'une addition de borax est encore plus frappant lorsque l'on considère la hauteur moyenne des plants. En effet, la hauteur des plants sans borax est de 9 pouces tandis que celle des plants qui ont reçu du borax est de 22 pouces. Dans le premier cas, il est évident que les plants n'avaient aucune valeur marchande;

3°. L'atrophie du cœur aussi bien que la gerçure des pétioles sont parfaitement enrayées avec 15 et 25 livres de borax à l'acre et imparfaitement avec 5 livres;

4°. Le nanisme des plants est encore apparent dans les parcelles qui ont reçu 5 livres de borax à l'acre tandis que l'enfouissement de 15 livres à l'acre donne une croissance normale;

5°. Une incorporation de 25 livres de borax à l'acre semble dépasser l'optimum. Cependant le feuillage n'a manifesté aucun symptôme d'intoxication.

6°. Les amendements calcaires ont un effet définitivement nanisant et favorisent la gerçure des pétioles et l'atrophie du cœur.

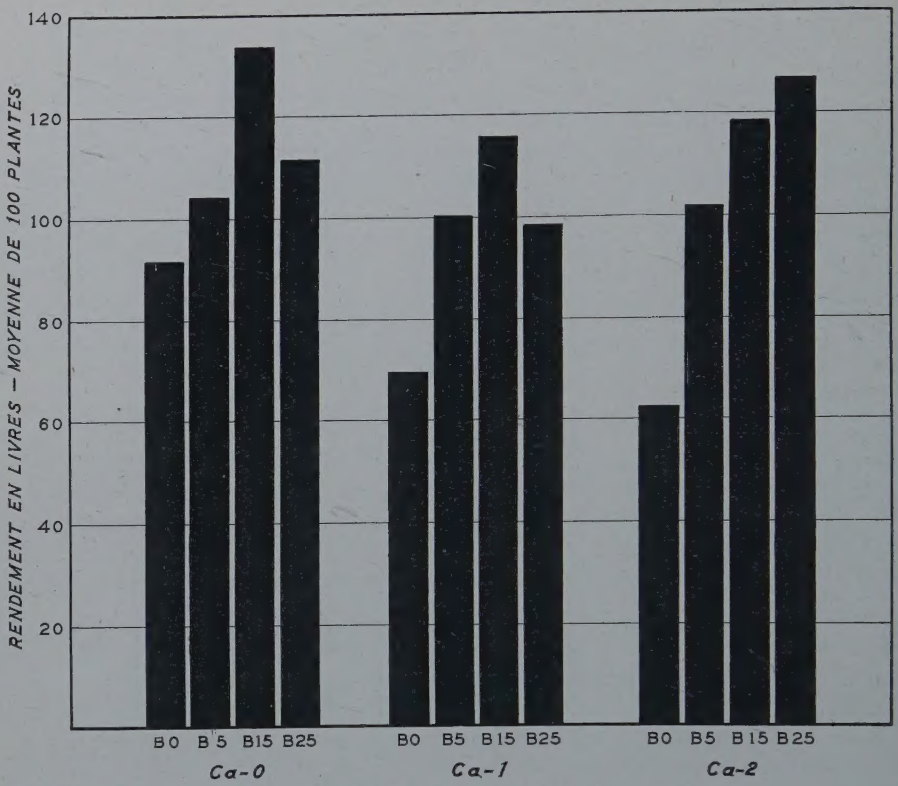

FIGURE 5. L'effet du borax et de la chaux sur le céleri.

DISCUSSION ET CONCLUSIONS

Même avec les résultats d'une seule année d'expérimentation, il est évident que la gerçure des pétioles et l'atrophie du cœur ont pour cause commune la carence de bore. D'où les auteurs proposent de maintenir l'appellation de "gerçure des pétioles" pour désigner les effets de la carence de bore dont la manifestation extrême est l'atrophie du cœur.

On peut distinguer, sur le céleri, trois degrés dans les manifestations externes d'une carence de bore. La première est l'apparition de gerçures sur les pétioles. Lorsque la déficience du sol en bore s'accentue, les plants deviennent nains. Enfin, lorsque le bore est totalement ou presque absent ou insoluble, l'atrophie du cœur se produit.

Ces expériences confirment l'opinion générale que la chaux est une cause indirecte des maladies par carence de bore en rendant insoluble le bore présent dans le sol.

Une quantité de 15 livres à l'acre de borax devrait être incorporée au sol soit au moment de la plantation, lorsque cette maladie a été observée l'année précédente, ou encore dès que la gerçure fait son apparition au cours de la saison de végétation.

RÉSUMÉ

1. L'atrophie du cœur du céleri causée par carence de bore est décrite. Les auteurs la considèrent comme un symptôme extrême de la gerçure des pétioles.

2. Les manifestations de carence de bore varient suivant la déficience plus ou moins prononcée du sol en cet élément. Les symptômes par ordre de gravité sont: la gerçure des pétioles, le nanisme et l'atrophie du cœur.

3. Il semble exister une relation entre l'incorporation d'amendements calcaires et la présence de la gerçure des pétioles.

4. L'enfouissement de 15 livres de borax à l'acre corrige les maladies du céleri par carence de bore sur les terres humifères acides et permet une croissance normale.

REMERCIEMENT

Les auteurs désirent exprimer leur reconnaissance à Monsieur C. E. Ste-Marie, régisseur de la Station Expérimentale Fédérale de Cap-Rouge à cette époque, pour leur avoir permis de poursuivre ce travail que la fermeture de cette station a malheureusement interrompu.

BIBLIOGRAPHIE

1. FOSTER, A. C. and C. R. WEBER. Celery Diseases in Florida. Fla. Agr. Exp. Sta. Bull. no. 173:58. 1924.
2. GRAM, E. Bormangel og nogle andre mangelsygdomme Tidskr. Planteavl 41: 401-449, 1936. (Résumé anglais p. 449).
3. PURVIS, E. R. and R. W. RUPRECHT. Cracked stem of celery caused by a boron deficiency in the soil. Univ. Florida Agric. Exp. Sta. Bull 307, 1937.
4. RICHARDSON, J. K. Studies on Blackheart, Soft-Rot and Tarnished Plant Bug Injury of Celery. Can. Journ. Res. 16: 182-193. 1938.

ENGLISH SUMMARY

EXTREME CASE OF CRACKED STEM OF CELERY

1. Heart atrophy in celery, due to boron deficiency, is described. The authors consider it as the most severe symptom of cracked stem.

2. The manifestations of a lack of boron in celery vary according to the extent the soil is deficient in that element. The symptoms on celery appear in the following order: Stem-cracking, dwarfing, and heart atrophy.

3. There seems to exist a relationship between applications of lime and the appearance of cracked stem of celery.

4. An application of 15 lb. of borax per acre prevents this celery disease on acid muck soils and permits normal growth.

BOOK REVIEW

FIELD CROPS AND LAND USE. By Joseph F. Cox AAA, Extension Agronomist, U.S.D.A., and Lyman Jackson, President, South Dakota State College. 473 pages, illustrated, published by John Wiley & Sons, Inc., New York. 1942. $3.75.

This book supersedes *Crop Management and Soil Conservation*, by the same authors, and *Crop Production and Soil Management*, by the senior author. The subject matter has been completely revised in keeping with modern trends in crop production and soil conservation, based on the results of the work of Agricultural Experiment Stations and the United States Department of Agriculture. Considerable emphasis is placed on the importance of crop production to the nation's prosperity in war time, as well as after the war is won.

The book is divided into two parts. Part 1, of a more general nature, deals with the place of agriculture in national life; the classification of field crops and their adaptation to various climatic zones; and crop management to conserve agricultural resources. Soil conservation is discussed under the headings of ploughing, fitting, cultivating the soil, and maintaining and improving soil fertility. A chapter is devoted to the subject of weed control and one to the control of crop pests, while others cover the growing of green-manuring and supplementary feed crops, pasture management, seed growing, and growing feed and cover crops for conservation of wild life.

Part II includes a detailed discussion on methods of growing each of the field crops commonly grown in the United States and Canada. This section presents a vast fund of information in regard to each crop as related to soil and climatic adaptation, fertility requirements, crop rotation, seed bed preparation, methods of seeding and harvesting.

An excellent bibliography provides a source of information for many topics connected with field crop production. A well arranged appendix lists the percentage composition of feedstuffs used in animal feeding, crop varietal recommendations by States, with a special list of Canadian varieties, as well as other useful information.

The book is highly recommended for use by farmers, scientists, extension workers, and students of agriculture.

P. O. R.

ERRATUM

In *Scientific Agriculture* 23 : (2), for October, 1942, in the article by W. A. Stephen entitled "Studies on the effect of liquid air, rays, and emanations on honey yeasts," the first line of paragraph 4, page 125, should read "Hertzian waves of 2.5×10^{11}" instead of "2.5×10^{1}".